



PHD

The creation of a method to measure and compare product appearance

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Award date:
2012

Awarding institution:
University of Bath

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THE CREATION OF A METHOD TO MEASURE AND COMPARE PRODUCT APPEARANCE

Volume 1 of 1

Charles Henry Ranscombe

A thesis submitted for the degree of Doctor of Philosophy

University of Bath, Department of Mechanical Engineering

MAY 2012

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Dedications

For family,
friends
&
Felicity

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Glossary

CI – ‘Central Intake’, the name of the air intake situated centrally at the front of a vehicle.

DLO – ‘Day-Light Opening’, the term used to describe windows, front and rear windshields, and sun-roof of a vehicle.

Feature – The term used to describe a particular aspect or part of a product’s appearance.

Extrema – Collective term for points that are situated furthest from a given location (extreme) in a given direction.

Form – The visible aspect of an object or product such as shape or configuration, distinguished from colour.

Graphics – This term refers to what can be described as ‘markings’ on the vehicle including details such as headlamps, radiator grille, number plate and emblems/badges.

Grille – A feature fixed in the body of a vehicle in front of the radiator. Usually located centrally at the front of the vehicle.

LSIC – ‘Lower Side Intake Cluster’, the term to describe the air intakes situated on the lower outer sides of a vehicle, often including other features such as fog lights.

Maxima – Collective term used to describe maximum coordinates in a given direction.

Minima – Collective term used to describe minimum coordinates in a given direction.

Organic – Discussed in reference to ‘form’. A term to describe embodying smooth curving shapes as opposed to rectilinear shapes.

Smartphone – Type of mobile telephone with incorporating additional computer technology.

Styling. – The term for the process focussing specifically on developing the appearance of a product.

Styling (used as a noun) – The term used to describe an object or product’s appearance, the outcome of the styling process.

Visual decomposition – The name given to the process of isolating features within a product’s appearance for further investigation.

Visual branding – Aspects of appearance that signify a particular brand.

Acknowledgements

First and foremost I would like to acknowledge my supervisors Dr Ben Hicks and Professor Glen Mullineux for their support and guidance throughout this project. I would particularly like to acknowledge Ben's encouragement and the time he has spared in many lengthy meetings. I also acknowledge Glen's help in creating much of the software during this research without which it would have been impossible to proceed.

I would also like to acknowledge Dr Baljinder Singh who also generously devoted much time and effort in creating the surveys used throughout the first year and a half of my research.

I acknowledge Mark Richardson, Pete Elliot and Ilya Fridman as well as all of the other members of staff at the Monash University faculty of Art and Design for the insightful discussion of their experiences in the automotive world and encouragement, as well as their friendly and welcoming attitude.

I must also gratefully acknowledge the Innovative Design and Manufacturing Research Centre at the University of Bath, for providing studentship from the Engineering and Physical Sciences Research Council (EPSRC) under Grant number reference GR/R67507/01.

Finally I must acknowledge all of the other friends and colleagues that I have had the pleasure to meet and work alongside, without whom the experience would not have been as cheerful and enjoyable.

List of publications

Journal papers

RANSCOMBE, C., HICKS, B., MULLINEUX, G. & SINGH, B. 2012. Visually decomposing vehicle images: Exploring the influence of different aesthetic features on consumer perception of brand. *Design Studies*. 33, 4. pp 319-341. DOI: 10.1016/j.destud.2011.06.006

RANSCOMBE, C., HICKS, B. & MULLINEUX, G. 2012. A method for exploring similarities and visual references to brand in the appearance of mature mass-market products. *Design Studies*. 33, 5. pp 496 - 520. DOI: 10.1016/j.destud.2012.04.001

Conference papers (peer-reviewed)

RANSCOMBE, C., HICKS, B., MULLINEUX, G. & SINGH, B. 2010. Vehicle design and brand perception: an investigation into visually decomposing product forms. *International Conference on Design and Semantics of Form and Movement 2010 (DeSForM)*. Lucerne, Switzerland: Design Research Society

RANSCOMBE, C., HICKS, B., MULLINEUX, G. & SINGH, B. 2011. Characterizing and evaluating aesthetic features in vehicle design. In: CHAKRABATI, A. (ed.) *International conference on research into design (ICoRD '11)*. Bangalore, India: Research publishing.

RANSCOMBE, C., MULLINEUX, G. & HICKS, B. 2012. Evaluating similarity and exploring branding in vehicle styling using fourier decomposition. In: STORGA, M. (ed.) *12th INTERNATIONAL DESIGN CONFERENCE - DESIGN 2012*. Dubrovnik - Cavtat - Croatia: The Design Society.

ABSTRACT

Product appearance plays a significant role in generating appeal for consumers and subsequent commercial success for mass-market products. Associated with the design and manufacture of many mass-market products is significant financial investment and thus also significant risk. This risk is particularly severe for established or mature markets such as consumer electronics and vehicles where designs must retain a brand identity and differentiate from other products while still being easily identifiable, and avoid potential design right or trade dress infringement.

Within the design process there is ‘styling’, the activity primarily concerned with the creation of products’ form and appearance. While appearance is the primary concern in styling there is a wide range of factors that must be considered alongside appearance when designers evaluate potential design concepts. While there exists many tools and methods to objectively evaluate and communicate factors such as cost, performance, manufacture or ergonomics, there are few strategies to assist designers in objectively evaluating and reasoning on appearance, despite its relative importance to the market success of products.

The aim of this thesis is to improve the styling process by researching and creating a method to more objectively measure and compare product appearance. In proposing a method and achieving the aim three major areas of research are addressed. The first is to create an approach to visually decompose products into constituent features to explore their influence on overall appearance. The second is to create a method of measurement to analyse the geometry of features and enable comparison across product ranges. The third is to investigate how the measures can be applied to assist designers during the styling process and provide insights into the strategic use of visual branding.

The progression through these research areas and the subsequent proposed method form the key contribution to knowledge of this thesis. Through the application of the method to various case studies and a comprehensive study in its complete form, the method is validated and its potential use to designers demonstrated.

1 INTRODUCTION

Not every car is a design classic. However, whether identifiable as a timeless icon, universally disliked or just wholly unnoticeable, every car *is* designed. The role of the designer in its broadest sense is to improve the life of the consumer through the things they design (Genius of Design, 2010). The way in which artefacts or products do this is by serving a purpose, meeting a need or fulfilling a desire (Genius of Design, 2010). The main subject of this research is the process followed by designers to create such things and ensure that they meet the needs and desires of consumers to the extent that they will invest in them.

Much of modern society is fortunate enough to have a great deal of consumer choice in terms of just about every product or service. While this choice provides a luxury to society it provides an important consideration for designers. It means that, for a product to be judged as successful it must not simply serve a purpose, meet a need or fulfil a desire, but do all of these things better than its competition. Previously, products would compete in the marketplace based on performance alone. Such is the way that modern consumer society has developed considerations on the potential success of products need to extend far beyond the basic evaluation of performance considering other ways in which products can become more desirable than their competition (Karjalainen and Warell, 2005, Warell et al., 2006).

Throughout the history of mankind, people have valued and desired visually beautiful or aesthetically pleasing objects. From ancient jewellery or earthenware pots to the latest mobile phone or car, consumers strive to own the product that they deem to ‘look good’ (Bloch, 1995, Kreuzbauer and Malter, 2005, Moulson and Sproles, 2000, Page and Herr, 2002, Creusen and Schoormans, 2005). It is certainly unlikely that a consumer will desire a product if, in their opinion, it doesn’t ‘look right’. The concept of designing things to look good or look right forms a key driver for this research, principally the concept of generating desire for products through appearance.

This research considers one product in particular, the car, as the focus of the research. The car/vehicle is selected as it is contended to be an exemplar product for which appearance plays a significant role in creating or exacting desire from consumers. The

car is not singular in exhibiting this quality, indeed what makes the car such a worthwhile product for research is the scale on which it is produced. Development time to take a car design from concept to sales can take from 4 to 7 years requiring multi-million dollar investment depending on the extent/newness/novelty of the design (Sobek et al., 1999, Thomke, 2001, BMW, 2011). Thus with this element of risk combined with the emphasis on appearance, the vehicle becomes a particularly important product to study.

Although vehicles and vehicle design is the central focus for this research, it is further shown throughout the thesis that there are a large number of similarities between vehicles and all mature mass-market products. Some examples include consumer electronics such as smartphones, computers, televisions and cameras and home appliances such as kettles, toasters, vacuum cleaners.

The following sections consider the central concept of appearance from a number of perspectives (illustrated in Figure 1) in order to elaborate on it. The first perspective is that of the design process and specifically the activities that a designer engages in order to create products. The second perspective considers the consumer, the object of the design efforts, and the mechanisms that allow for communication and the eventual generation of desire. The final perspective considered is that of the marketplace and in particular the strategic uses of appearance to create desire.

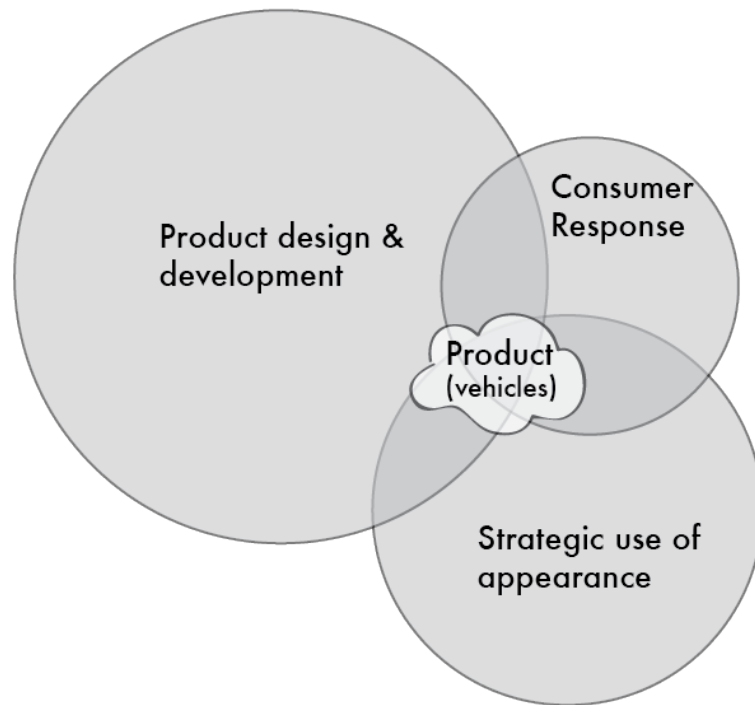


Figure 1 Illustrating the topics incorporated in the introduction where circles represent the topics and their size the relative emphasis in this research

1.1 Product design and development

The first perspective considered is the product design and development process. In other words this is the process by which products are created and hence the point at which decisions over almost every aspect of their eventual form are made.

This section provides an introduction to the various models for product design and development, considering and comparing vehicle design development within these models. Lastly the sub-process that is primarily concerned with the generation of the appearance of vehicles, known as Styling design, is reviewed. This focusing of research through the product design and development process is illustrated in Figure 2.

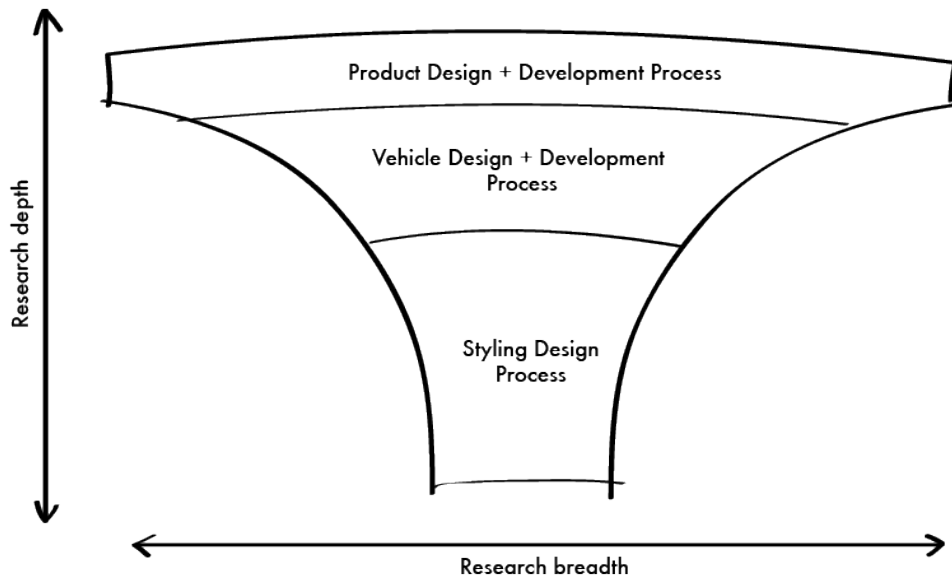


Figure 2 Illustration of background research in product design development processes

When discussing product design and development, activities of marketing, design and manufacture are also considered. Ulrich and Eppinger (2008) differentiate a product from the product development. A product is ‘something sold by an enterprise to customers’, where product development is defined as ‘the set of activities that begin with perception of market opportunity and ending in production, sale and delivery’. Hence, the review of product design and development does not just include the physical activities of product design but the stages preceding and subsequent stages that shape the form development of the design into a saleable product. By considering the product design and development process as a whole, and subsequently the vehicle design and development process, the considerations that surround the creation of products are also introduced. This in turn helps to understand the origin and rationale for constraints and influences that play a major role in formation of products.

In consideration of both generic product design and development models (Clark and Fujimoto, 1991, French, 1985, Pahl and Beitz, 1996, Pugh, 1990, Roozenburg and Eekels, 1995, Ullman, 2003, Ulrich and Eppinger, 2008, Sobek et al., 1999) and those for the vehicle design and development model a number of important themes can be identified as being common. The models represent an open ended, iterative, and sequential workflow. These models also show that designers are provided with a basic set of requirements, on which further information is accumulated and designs embodied.

Most importantly, models also highlight the need for evaluation within the design and development process. It is the constant evaluation of information/designs throughout the process that evolves designs from an initial statement to their fulfilment.

In terms of the motivating factors that drive the design process three common areas are raised. These are marketing, technological and commercial considerations (Bangle, 2001, Clark and Fujimoto, 1991, Sobek et al., 1999, Thomke, 2001). These areas and their factors form the criteria against which designs are evaluated and assessed during development, and thus drive the development process itself.

These factors are also inherent in the styling design process. As with the general design process, the iterative and sequential nature of the process is guided by evaluation and assessment. The literature also highlights the presence of the three high level factors (marketing, technological, and commercial) in the process and hence in evaluation of designs. Thus the role of the designer within the styling design process can be considered to involve the evaluation of appearance with respect to these three dimensions.

What should also be noted about the dimensions is that they include both tangible and intangible aspects. Examples of tangible aspects can include factors such as materials, manufacture and cost that are relatively easily and objectively evaluated. Examples of intangible factors include fashions, trends or branding requiring subjective evaluation and as such make styling relatively difficult to evaluate.

1.2 Consumer response to product appearance

The primary perspective of the research in this thesis surrounds the creation of products, focusing particularly on the creation of desire through products' appearance. This can be said to only consider one side of the equation. Designers create objects with the intention that they will be received in a particular manner. Thus there is a need to gain some understanding of a product's reception by their target, the consumer. Thus the other side of the equation is the consumer and the mechanisms by which products communicate, their perception and consumer response to them.

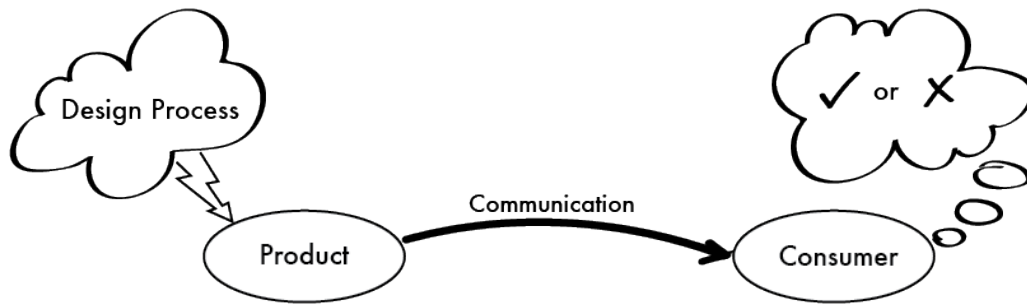


Figure 3 Illustrating both sides of the 'equation' the product and the consumer

Implicit in the discussion of product appearance (1.1), creating desire is the theory that products communicate, or are a medium for communication with the consumer (Crilly et al., 2008a, Crilly et al., 2008b, Crilly et al., 2004, Crilly et al., 2009, Desmet, 2003, Desmet, 2006, Monö, 1997).

A number of models have been put forward for the communication of designers' intentions to consumers through products (Monö, 1997, Schramm, 1961, Shannon, 1993). These models state that it is possible to elicit reactions from consumers through the visual properties of objects. There is some discussion as to the need for common experiences and references between designers and consumers (Crilly et al., 2008a, Crilly et al., 2008b). However the underlying point of these findings is that designers heavily influence consumer's response to product appearance.

Another side of the discussion of the consumer is the formation of response based on communications through products. It is widely acknowledged that products can elicit emotional responses on a number of different levels (Baxter, 1995, Crozier, 1994, Cupchik, 1999, Desmet, 2003, Jordan, 2000, Lewalski, 1988). Knowledge of the cognitive mechanisms behind consumer appreciation of aesthetics further informs measures taken by designers when considering aesthetic qualities. It also highlights the specific types of cognitive response most relevant to the scope of this study such as visceral and reflective responses.

1.3 Product marketing: the strategic use of appearance

The final perspective discussed relates to the environment or context of products, their appearance and associated consumer response. This is to say the strategic use of product appearance in the modern marketplace. A review of the strategic use of appearance gives insights into the possible considerations designers make and thus a greater explanation of the motivations behind evaluation of appearance during the design process.

It is acknowledged that consumers desire newer and improved products, whether visually or functionally (Belk et al., 2003, Cappetta et al., 2006, Millman, 2011b, Moulson and Sproles, 2000). Thus in consideration of appearance a new product should be recognised by the consumer as being novel, while it is also known that products should also be familiar in some respects or foster recognition (Millman, 2011a, Moulson and Sproles, 2000, Person et al., 2008, Person et al., 2007). This raises a central compromise that lies at the heart of almost all decisions on appearance. Products need to be suitably novel while also suitably familiar and recognisable (Millman, 2011a). This compromise is now elaborated on in consideration of the different strategic use of appearance in marketing products.

Person et al. (2008), Moulson & Sproles (2000), and Duncan quoted in Millman (2011a) discuss the role of appearance in making products distinct from other products, yet maintaining a level of identity or being familiar within a company's product range. This presents the compromise in terms of using products' appearance to be either distinct from some products while being similar to others. This is now illustrated in terms of considerations made by designers within the aforementioned compromise between familiarity and novelty (Figure 4).

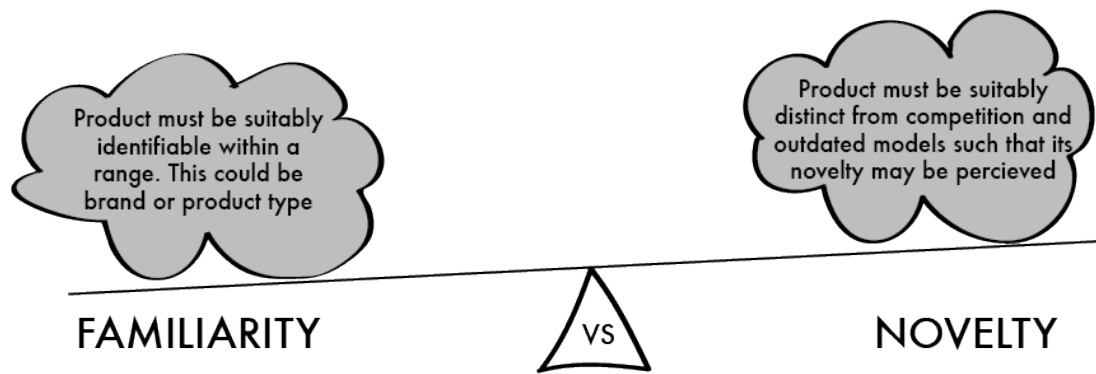


Figure 4 Illustrating examples of compromises relating to product distinctiveness

As a development on the theme of products as a medium for communication, a number of academics (Crilly et al., 2004, Monö, 1997, Norman, 2002) make reference to the function of aesthetics to help users understand product functions and properties. This can be classed as a marketing strategy as these expressions of function and properties help consumers to identify the type of product they are viewing, hence they can be used to align products with a product group or product type. This is now illustrated in terms of considerations made by designers within the context of the compromise between familiarity and novelty (Figure 5).

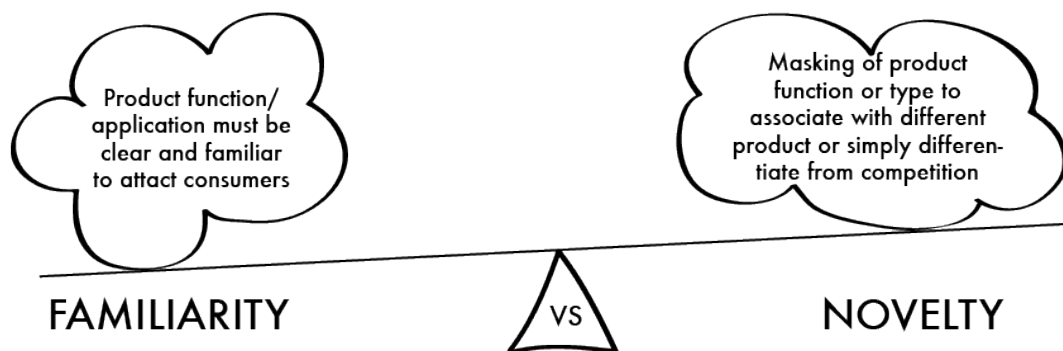


Figure 5 Illustrating examples of compromises relating to communication of product function

As a further strategic use of appearance, Pesendorfer (1995) and Sproles (1981) discuss the occurrence of fashions and trends within societies and how they evolve. Cappetta et al. (2006) discuss careful use of aesthetics to align a product's style with those associated with social trends or fashions, making products more attractive to specific consumer groups. With the observation of aesthetics being used in such a way, there is also further discussion on the need for these aesthetics to continually change with the evolution of styles and trends, in order that the same specific consumer groups

continue to find the product appealing. This is now illustrated in terms of considerations made by designers when balancing familiarity and novelty (Figure 6).

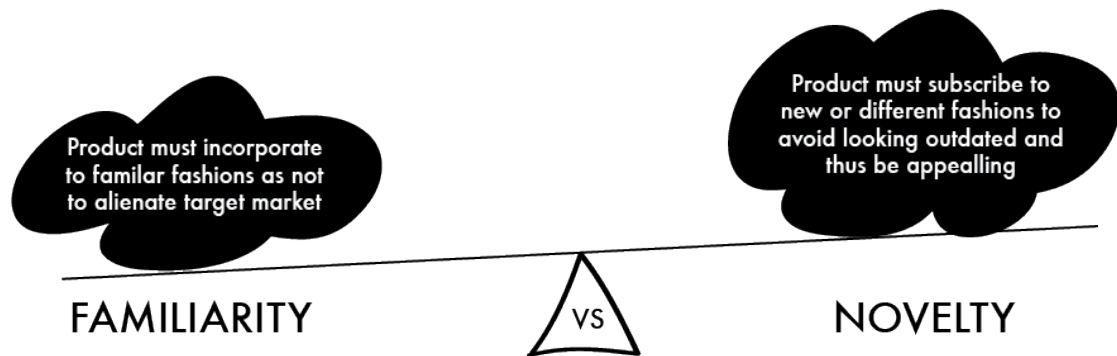


Figure 6 Illustrating examples of compromises relating to communication of product function

Intrinsically linked with the ideas of perception of products and their appearance is the concept of brand. Derived from the use of firebrands to mark the origin and ownership of livestock, the concept of brand has evolved a long way in current marketing. Nowadays the definition of brand is particularly broad and can encompass any manner of meanings for any number of products or services (Keller, 2008, Millman, 2011a, Millman, 2011b, Roellig, 2001). What can however be defined clearly is the importance placed on it and its successful management and use in marketing products (Karjalainen and Snelders, 2010b, McCormack et al., 2004, Person et al., 2007).

As with appearance, brand plays a role in generating appeal for products (Keller, 2008). Importantly both are linked in that appearance has been shown to be the primary channel for a product's brand to be communicated to the consumer (Bloch, 1995, Karjalainen and Snelders, 2010a, Page and Herr, 2002). Thus considering the importance of communication through product appearance and the various roles of appearance in marketing of products, brand becomes an all encompassing notion or concept that must be considered alongside the individual specific function of appearance raised in the aforementioned paragraph (illustrated in Figure 7). Thus due to the strong relation of brand with appearance and the importance placed upon brand identity by companies, branding forms a key topic considered in this research.

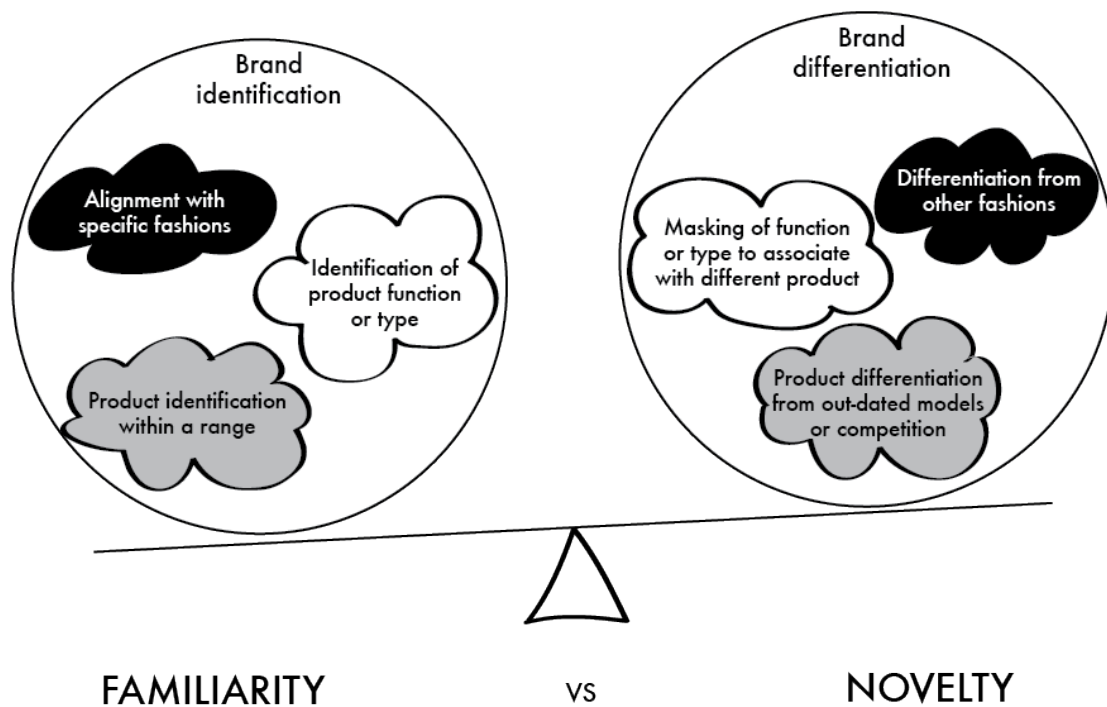


Figure 7 Consideration of branding in the central compromise encompassing different strategic uses of appearance

1.4 The role of the designer: the juggler

In introducing the three perspectives on appearance and products (1.1-1.3) three crucial points are raised. Beginning with the perspective of the consumer, it has been shown that designers can communicate and attempt to elicit desire through the appearance of products. With respect to the use of appearance in marketing, it is shown that the strategic use of appearance to elicit desire is applied in a number of facets including distinctiveness versus familiarity, communication of function, fashions and visual branding. Thus considering all of these facets can make evaluation particularly complex. Finally considering the process of design it has been shown that an integral aspect in the creation of products is the requirement for the designer to evaluate and judge the possible success of design and thus appearance. Derivation of these points is illustrated in Figure 8.

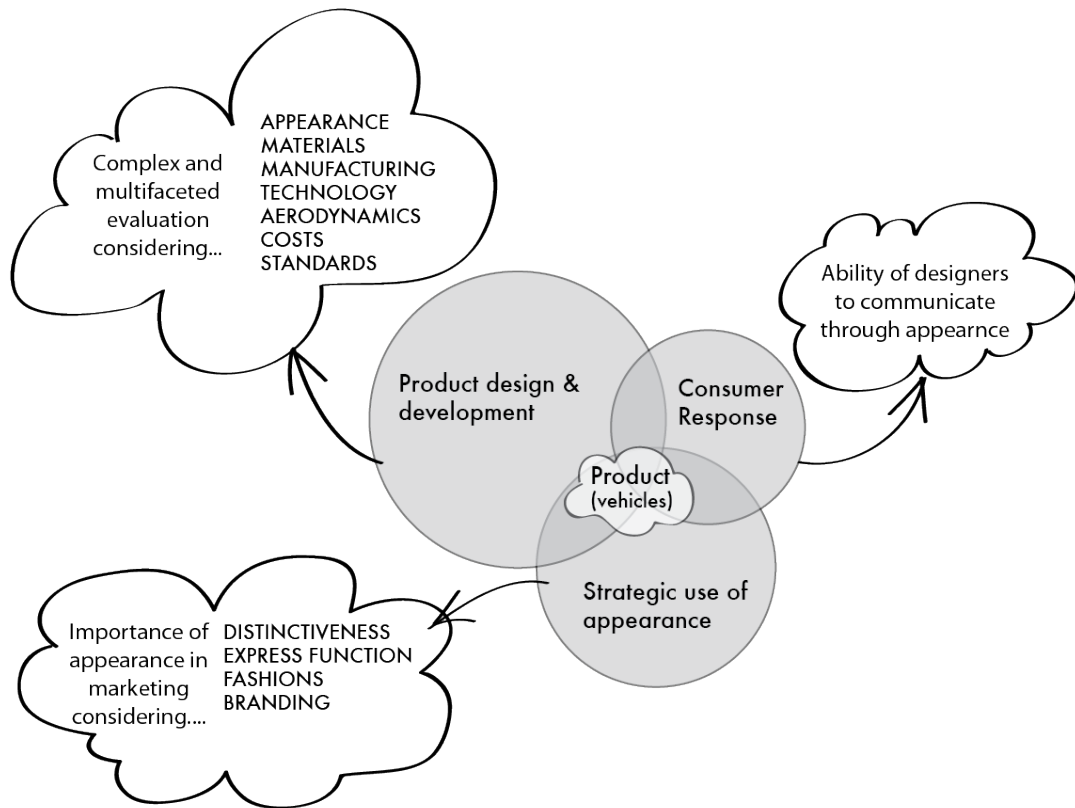


Figure 8 Key outcomes from perspectives introduced

It must also be acknowledged that these considerations are concurrent with, and sometimes merely supplementary to the encompassing input factors (marketing, technical, commercial) raised in 1.1. Thus designers, while considering appearance must also consider constraints deriving from technical performance, production costs, manufacturing capability, ergonomics, and legislation (Bloch, 1995). These further factors can be said to be tangible or objective while factors relating to appearance may be said to be intangible or subjective.

The ability of a design to meet many tangible factors can be evaluated objectively, indeed there are various approaches proposed to assist the designer in this (Dahan and Hauser, 2002, Krishnan and Ulrich, 2001) such as quality function deployment (QFD), the FMECA standard (Carlson et al., 1996, SAE, 2009), and the analytic hierarchy process (AHP) (Ayaü, 2005, Vaidya and Kumar, 2006). While evaluation strategies exist for many tangible aspects of designs, crucially assessment of product's appearance remains highly subjective and ill defined. Designers and managers concerned with this aspect of vehicle design presently rely on previous experience, training and the notion of designer's intuition when considering visual qualities of

design proposals, despite the impact these judgements have been shown to have on the vehicle's market success (1.3).

Thus the analogy of the role of the designer as a juggler is introduced (Figure 9). The range of factors/constraints impacting design are analogous to balls, all of which the designer must juggle to create a successful solution. While the tangible objective factors are reasonably well defined and easy to catch, the intangible/subjective factors can be much harder to manage. Thus this research will focus on the intangible/subjective factors and consider ways in which their consideration or handling during the design process can be improved.

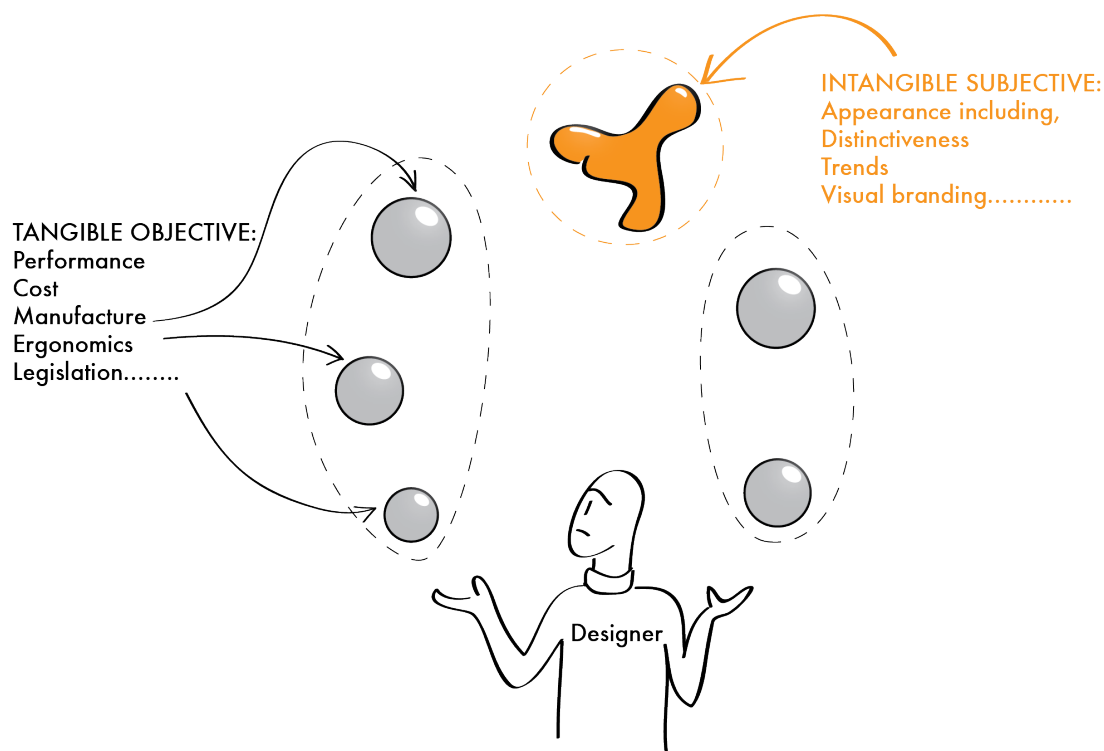


Figure 9 Illustrating the analogy of the designer 'juggling' different factors to create successful designs

1.5 Previous research to assist in vehicle styling

Based on existing literature, research to support the styling process can be considered to fall into three areas. The first relates to earlier stages in the styling design process concerning the generation of concepts. A large volume of work has been undertaken into the use of shape grammars (Chau et al., 2004, Chen et al., 2004, McCormack et

al., 2004, Pugliese and Cagan, 2002, Smyth and Wallace, 2000, Stiny, 1980, Weifeng and Jianghong, 2006, Yannou et al., 2008a) providing designers with exhaustive and potentially inspirational concepts for development in the design process. While these approaches use objective rules (geometry based) for the creation of concepts and in some cases the iterative development (Orsborn et al., 2008, Orsborn et al., 2006), much of the evaluation of resulting appearance remains subjective. In addition research has been undertaken examining the idea generation process itself and the continual evaluation by designer during the design process (Buxton, 2007, Prats et al., 2006, Tovey, 1992, Tovey et al., 2003). Although evaluation of appearance is addressed, rationale behind the evaluation is subjective.

The second major area for research concerns the latter stages of the design process. Much of the research into these stages of the styling design process focuses on the improvement of the styling process through the development of supporting tools such as digital tape drawing (Balakrishnan et al., 1999, Grossman et al., 2001), sketch based inputs (Bae et al., 2003, Fleisch et al., 2004, Kara et al., 2006, Kara and Shimada, 2008) and developments in surface modelling software (Mattison, 2006b, Mattison, 2006a). Here there is an overriding trend in the development and improvement of software or software based environments, that aim to make the tools used by designers simpler and thus improve the efficiency of the process. It follows that further study based on such developments is rooted in the improvement of software and associated technology, and underlying techniques for representing geometry.

The final category considers the styling design process within the overall design and development process and its management. A substantial body of work carried out under the European projects FIORES and FIORES II aim to make improvements to the process by considering the flow and management of information through the styling design process (Catalano et al., 2007, Cheutet et al., 2005, Giannini et al., 2006, Podehl, 2002). This type of approach has also been considered outside of the FIORES projects (Attene et al., 2009, Chung and Lee, 2007, Nyirenda et al., 2006, Wei et al., 2006).

While the outcomes from the second and third areas do assist the designer in terms of their ability to create and communicate designs, the actual evaluation of appearance

still remains relatively subjective. Hence the main contribution of this thesis is concerned with making the subjective evaluation of appearance more objective.

1.6 Aims & objectives

The importance of appearance in product design and development has been discussed. Through consideration of this importance from different perspectives the use and management of appearance has been further elaborated. This in turn shows the requirement for designers to make difficult and subjective evaluations on a particularly important aspect of a product's design. Subjectivity in evaluation of appearance has also been shown to be an aspect of the styling design process currently lacking support and requiring scientific research. It is this gap in supportive tools and methods that is dealt with in this research and leads to the following aim.

To provide insights to support the styling process through the creation of a method to measure and compare product appearance

It is expected that by achieving this aim designers will have an improved platform from which to reason about styling decisions and put forward clear rationale which can be easily communicated through design teams as well as other associated teams such as marketing and engineering.

This aim leads to the following research questions

- RQ1 How does the geometry that defines product appearance relate to visual branding?
- RQ2 How can feature geometry be used to objectively measure and compare product appearance?
- RQ3 How can the proposed approach be used provide insights to support the styling process?

Based on these research questions the following research objectives have been developed:

- I. Create a systematic method to decompose mass-market products' appearance into geometric features.
- II. Apply the method to investigate the influence of features and groups of features on product appearance and visual branding.
- III. Research and create an approach to measure and characterise features to enable comparison across similar products.
- IV. Create a software tool to analyse product appearance.
- V. Investigate how the method can be used to provide insights to support the styling process.
- VI. Demonstrate and validate the approach through case studies.

Following statements of the aim, research questions and objectives the research methodology is now set out.

2 RESEARCH METHODOLOGY AND THESIS SUMMARY

Referring to the research questions and objectives presented in the introduction the research methodology adopted for this research is given. Subsequently the structure of activities to implement the methodology and address research questions and objectives are now reviewed in the thesis summary.

2.1 Research methodology

Research question 1 is based on investigation and identification of ‘phenomena’, the phenomena being products’ appearance and particularly visual brand and its ability to communicate with and influence consumers. This is also echoed in objectives I and II which reference appearance, influence and visual branding. These phenomena are based loosely around concepts relating to consumer recognition and perception, hence they inherently involve the consumer.

This relation to the consumer means that research associated with objectives I and II moves toward an ethnographic approach. As a result there is a requirement to conduct some form of research relating product form to consumers and their perceptions of appearance and brand. By nature, this type of research methodology is qualitative, indeed Creswell (2003) states that the use of the word ‘explore’ is indicative of qualitative study.

Research question 2 explicitly references objective measurement. Thus objectives III and IV are concerned with the development of measures and their application in the measurement of appearance. Implicit in these objectives and the concept of measurement is quantitative analysis, requiring some form of numerical based investigation.

Research question 3 concerns the use and application of research to the designer and styling process. Thus objectives V and VI involve the validation of proposed methods

in consideration of the designer and styling process. Hence there is a return towards ethnographic research in that the knowledge generated through measurement is directed/considered in the context of designers, the styling process and the rationale for styling products to increase appeal.

Hence it can be said that the research methodology that is used in this project is classed as a 'sequential mixed method (Creswell, 2009, Creswell et al., 2003, Johnson et al., 2007) as it incorporates both qualitative and quantitative research activities and it is not possible to address all objectives and research questions without adopting these two types of approach. The different types of method are now illustrated in Figure 10 in the context of the progression of research.

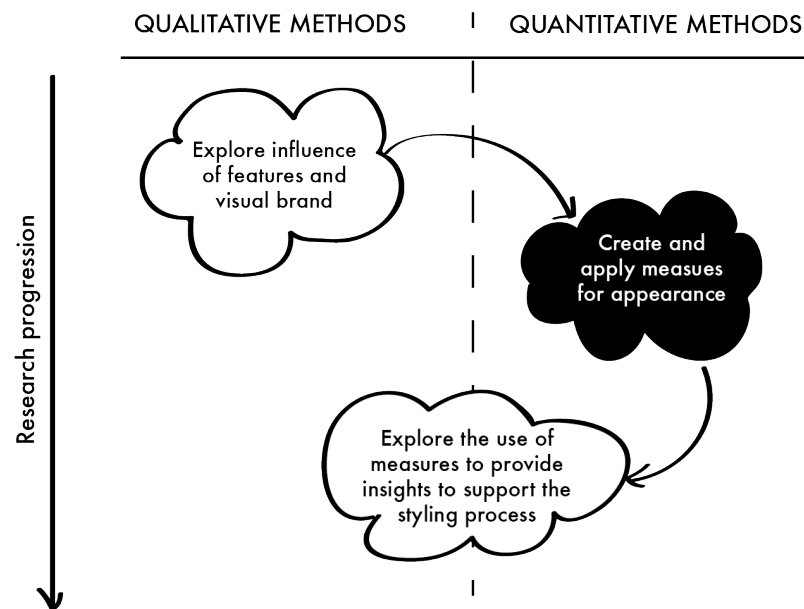


Figure 10 *Illustrating the mixed methods approach adopted for this research*

In consideration of the literature on mixed methods methodologies, this approach is said to adopt a pragmatist philosophy (Johnson and Onwuegbuzie, 2004, Creswell, 2009, Johnson et al., 2007). This is derived from the nature of the method drawing on two philosophies of positivism (associated with quantitative methods) and constructivism or relativism (associated with qualitative methods) considered by some to be incompatible (Howe, 1988, Denscombe, 2010).

The pragmatic philosophy behind the mixed methods approach is contended to mirror the intention of the thesis in linking the main areas of study and potential impact of the research. Product appearance and styling are held as being artistic and intuitive

processes, while the engineering and business processes that styling fits within are considered more objective (Cheutet et al., 2005, Giannini and Monti, 2002, Tovey, 1992). The interface of these philosophically/fundamentally different backgrounds can result in incompatibility and disagreement (Bangle, 2001) similar to those in methodological philosophies raised by Howe (1988). Thus a pragmatic approach is required if the two differing areas are to be considered concurrently. The details of the approach adopted to implement the mixed methods research methodology are now given.

Conceptual model

The basis of this research is the premise that product appearance and visual branding influence perceptions of product and the brand image of the company that produces it. The first step in the research methodology is to propose a conceptual model that embodies this premise and subsequently test it. This is achieved through the use of surveys. This then provides the first methodological step to observe phenomena that will then be further investigated adopting quantitative methods.

Scoping study

Implicit in the notion of quantitative research is the concept of measurement. In order to provide designers with quantitative evaluation tools there must be quantitative analysis of designs. In other words assigning meaningful numerical values to features of a design such that they can be measured, compared and contrasted (Denscombe, 2010). In order to do this, some investigation into the feasible and relevant measures that may be applied to products' appearance must be carried out. This is achieved through a scoping study which proposes an initial approach for exploring appearance quantitatively. Results from the scoping study are then used to further develop a method capable of measuring appearance.

Testing proposed methods through case study

Following the proposal and assessment of measures, a set of initial data can be generated by applying the proposed method in a case study. Doing so generates a primary data set which may then be analysed for any patterns or trends within groups of geometry. Thus the use of the method created to provide insights may be assessed. The outcome of applying the method in a case study is expected to provide knowledge that may be used to further develop the method.

Reflection on the use of the method to support styling

The final step within the proposed research methodology is to link numerical data generated by measures to designers and the styling process. This is achieved by using data generated from numerical experimentation in consideration of knowledge about the styling process. Specifically this considers the information that provides the most insights to support the styling process in the evaluation of appearance. Thus the result of this research is a strategy uniting possible findings from measures with the requirements of designers. It is noted that this stage does not completely return to ethnography. To do so would require the use of the created method to be observed in industry. However, research to this extent is not within the scope of this thesis. Validation of the method is achieved conceptually through an additional case study.

2.2 Thesis summary

This section runs through the content of each of the subsequent chapters and their key contribution in the thesis. The sequence and content of chapters is summarised in Figure 11. Figure 12 relates content from each of the major chapters back to the research objectives, research questions and research methodology. Figure 13 illustrates the progression of the research to achieve aims by showing the different activities and methods adopted within chapters.

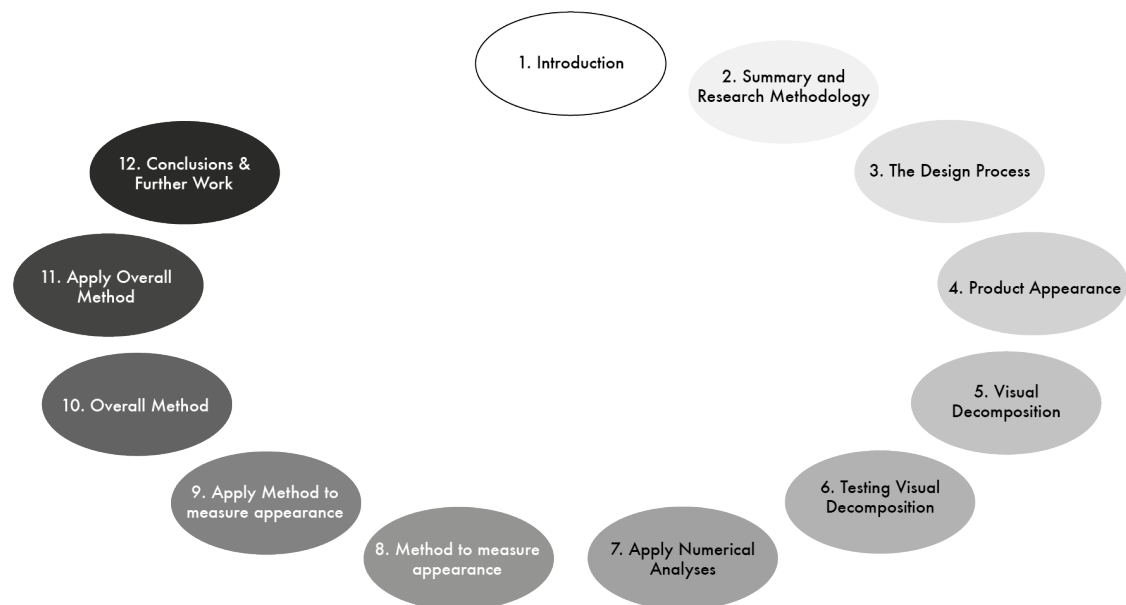


Figure 11 Sequence of chapters and summary of their content

The chapters following on directly from the introduction (3 and 4) focus further on the background of the research. Chapter 3 goes into greater detail in discussing models for the design and development process as well as going into specific detail on the vehicle styling process. This chapter also includes a detailed review of the literature reporting various strategies to assist in the vehicle styling process.

External factors influencing product appearance are covered in Chapter 4 which focuses on consumer response to appearance and its application in the marketing of products. The concept of brand is also elaborated on. The role of chapters 3 and 4 is to cement the requirement for research to be conducted by explaining the factors that contribute to the research problem. This is then used to further reinforce the key objectives used to achieve the research aim.

With the aims and objectives in mind it is possible to begin practical research. This is split between chapter 5 proposing a conceptual model and chapter 6, testing it. Visual decomposition is the title given to the technique which is created to isolate features within a product's appearance in order that their influence on the consumer may be explored. Chapter 5 presents the creation of the visual decomposition approach while chapter 6 discusses the approach to test it.

The contribution from these chapters is twofold. Firstly the experimentation with the method through its application gives some insights with regard to the influence of different types of features on recognition of brand. However, more importantly, the application of the visual decomposition approach validates the conceptual model which is most essential as it provides the conceptual foundation from which the overall method developed through this research is based.

AIM	RESERACH QUESTIONS	OBJECTIVES	CHAPTERS	METHODOLOGY
TO PROVIDE INSIGHTS TO SUPPORT THE STYLING PROCESS THROUGH THE CREATION OF A METHOD TO MEASURE AND COMPARE PRODUCT APPEARANCE	RQ1 How does the geometry that defines product appearance relate to visual branding?	I. Create a method to decompose classes of mass-market products appearance into geometric features.	5. Visual Decomposition	Propose conceptual model
		II. Apply the method to investigate the influence of features and groups of features on product appearance and visual branding.	6. Testing Visual Decomposition	Test conceptual model
	RQ2 How can feature geometry be used to objectively measure and compare product appearance?	III. Research and create an approach to characterise and measure features to enable comparison across similar products.	7. Apply Numerical Analyses	Scoping study
		IV. Create a software tool to analyse product appearance.	8. Method to Measure Appearance	
	RQ3 How can the proposed approach be used to support designers and provide insights to support the styling process?	V. Investigate how the method can be used to support designers during styling design	9. Apply Method to Measure Appearance	Case study
		VI. Demonstrate and validate the approach through case studies.	10. Overall Method	Reflection on the use of the method to support styling
			11. Apply Overall Method	Case study

Figure 12 Illustrating the flow of research to achieve objectives and answer research questions

Having developed the basis for investigation of appearance, and in accordance with the aims and methodology, chapter 7 addresses the numerical analysis of appearance. This provides the first step towards the objective assessment of appearance through a scoping study. The study uses the visual decomposition technique in conjunction with existing philosophies on facial proportions to explore the use of numerical assessment of appearance to review and characterise features. As this is a scoping study, the major contribution from the study is in the use of results to inform future use of the method. Results provide a number of guidelines for numerical/quantitative assessment of appearance particularly with regard to the type of analyses/measures used and the definition of features.

Following the scoping study, a method to measure appearance is proposed in chapter 8. Following on from the use of the visual decomposition method used throughout previous chapters, the contribution made by this chapter is the definition of measures

that can be applied to decomposed products. As well as defining the measures, this chapter also outlines the fundamental use of these measures in reviewing the degree of similarity/difference between products that forms the basis of objective evaluation of a number of products' appearance.

Subsequently chapter 9 reports the application of the proposed method in a case study. The proposed method (chapter 8) is applied to a limited range of visually more conservative and similar forms in order to truly test the method in its ability to highlight minor differences in a quantitative manner. The case study uses smartphones in direct competition and subject to allegations of intellectual property infringement. This context is used to explore the use of the method and the quantitative assessment of similarity to begin the exploration of the method to assess visual branding. As with the testing of the visual decomposition technique in chapter 6, the case study provides insights in terms of the appearance of products investigated and the efficacy of the method itself.

Much of the feedback on the use of the method proposed in chapter 10 relates to the consideration of product context with respect to application and interpretation of the measures used. Hence the overall method in chapter 10 is primarily concerned with the discussion of products' context and how analyses/measures may be applied to best provide insights to support the styling process. The major addition included in the refined method is the development of a product space to contextualise products investigated and specific analyses that can be applied with respect to products 'location' in the products space. Doing so then defines the way in which the method created is to be operated in order to provide insights to support the styling process. This instruction is provided in the form of guidelines.

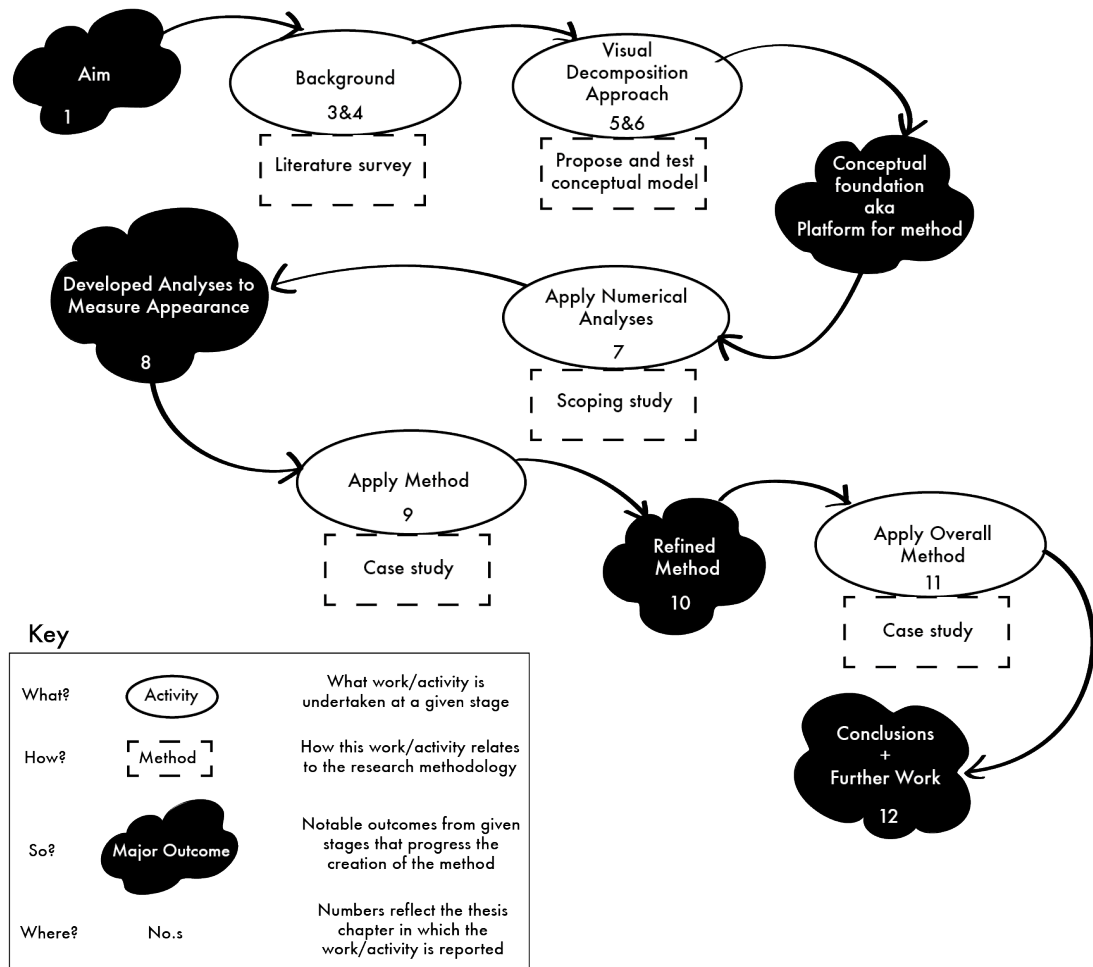


Figure 13 Illustration of the sequence of research activities, methodological steps and major outcomes reported in this thesis and the chapters in which they are included

Having fully refined the method that forms the main contribution to knowledge presented in this thesis, chapter 11 reports its validation through a second more exhaustive case study. The case study is aimed to simulate the method's full application as it would be used in industry. Hence a particular brand of vehicle is selected (BMW) and an exhaustive investigation of its current and previous vehicles is undertaken along with a range of competing vehicles. The method is validated through the findings highlighting particular aspects of appearance that contribute to visual branding. Interpretation of similarities relating to these findings is in turn used to recommend a number of future styling strategies, thus demonstrating the value of the proposed method to provide insights to support the styling process.

The final chapter (12) draws conclusions relating to the success of the research, and discussion of its ability to improve the vehicle styling process. This section also addresses some of the limitations associated with the method. Owing to the related

nature of the design process, many of the conclusions lead on to a discussion of further work. Much of the discussion is used to outline some of the further steps that could be taken to apply the method industrially and do so in a greater range of ways, thus further supporting the styling process through the objective evaluation of appearance.

3 PRODUCT DESIGN AND DEVELOPMENT PROCESS

This chapter reviews the general product design and development process and considers in detail the styling design process. Detailed information gathered from practising designers/stylists is used to present a consensual model for the design of vehicle appearance. This model is then used to provide context to an exhaustive review of the literature aiming to support and/or improve the styling design process.

The result of conducting this part of the literature survey is in two parts. The first is an in-depth understanding of the styling process which is used to inform the subsequent research in order that it be relevant to the processes adopted by practising designers. The second is the definition of a gap in the research landscape derived from the various different approaches that have attempted to improve and support the styling design process.

3.1 Generic design models

A number of different product design and development models exist all with slight differences in terminology. However, they share a common structure of the basic steps involved. A number of models have been proposed to summarise design and development processes (French, 1985, Pahl and Beitz, 1996, Pugh, 1990, Roozenburg and Eekels, 1995, Ullman, 2003) and BS 7000 standard.

All of the aforementioned models represent an open ended and iterative sequential workflow. These models also show that designers are provided with a basic set of requirements, on which further information is accumulated and designs embodied. Four key features have been identified as being common to design process models. These are:

Initial statement

Design and development models presented are in concurrence that the process begins with a statement of need. This is a set of basic requirements that form a 'specification'. The level of detail can vary widely between different projects.

Sequential

The product design development process is sequential by nature. Following the initial statement, a process of exploration of the statement of need, incorporating constraints, is undertaken in order to embody the form of the solution.

Iterative

The process includes a number of iterations. By exploring possible solutions to the need statement, ideas and information are generated and repeatedly assessed against the statement of need and constituent constraints that from the specification. Hence following these assessments new information can be added to the exploration of solutions and further developing them.

Evaluation

Following iterations and assessment of designs, there must also be some form of evaluation. Information from exploration is assessed against the design specification, and designers must evaluate outcomes of this assessment in order to proceed with further design development.

The Ulrich and Eppinger model is illustrated in further detail (Figure 14), as it is an example of a model of design and development process for mass-produced consumer products. Other models [6-10] relate more closely to low volume production engineering design processes. The generic production process model defined by Ulrich and Eppinger (Ulrich and Eppinger, 2008) gives an indication of the activities undertaken by marketing and manufacturing departments as well as design departments. The key stages that make up this model and the details of each stage included in Figure 14.

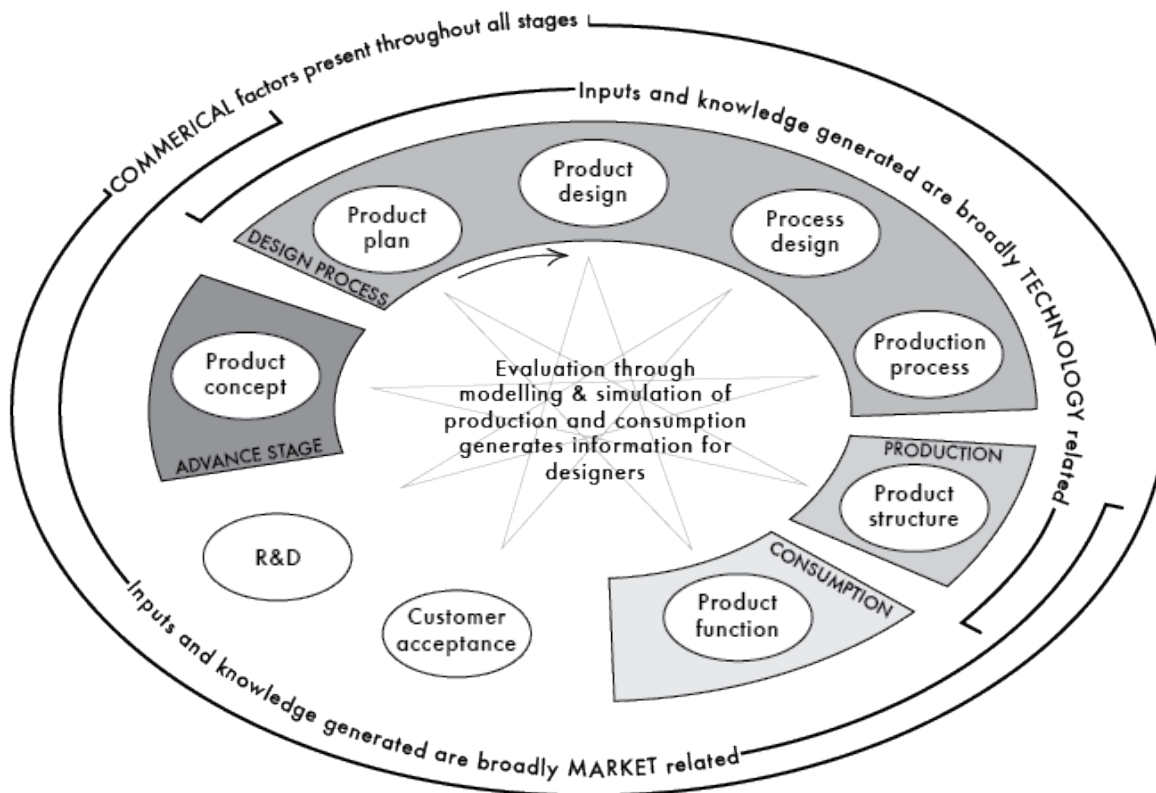


Figure 15 Clark & Fujimoto model of vehicle design and development process

Clark and Fujimoto outline three sets of inputs and constraints that drive the development of vehicle designs. Parallels can be drawn between these constraints, drivers and those highlighted by Pugh (1990) as part of specifications which fall broadly into three categories: marketing related, technology related or commercial factors. Broad input types are shown in context of the overall design and development process in Figure 15 and detailed further in the following sections.

3.2.1 Marketing related factors

- *Market input:* Market research carried out either in house or outsourced defines the market needs and gaps that the design should fill.
- *Strategic plans:* These include manufacturer/company strategy influenced by availability of technology and components, resource constraints and market constraints. However, these plans influence the product design directly in the

form of product specification defining such constraints as: price range, product image, engine choice and target customers.

- *Appearance*: Styling design within the automotive design and development process is chiefly concerned with the appearance of vehicles (Clements and Porter, 2007). Hence, the overall appearance of the vehicle and its impression form a major input to the design process.

3.2.2 Technology related factors

- *Technological development*: This acknowledges that there are instances when a company will develop new technology that drives the whole products design rather than certain parameters of it. For example, the inclusion of a new size of engine will have an effect on the overall perception of the product as it will appeal to a different target market. Conversely, product development can also drive new technology development.
- *Aerodynamics*: Catalano et al. (2002) further acknowledge that aerodynamic properties provide constraint on design development of product form due to their influence vehicle efficiency.
- *Manufacture*: Designers are aware of the manufacturing capabilities available, whether in house or out sourced. These are considered during design to ensure all proposals can feasibly be produced.

3.2.3 Commercial related factors

- *Cost of time and resources*: It is clear that vehicle manufacturers desire their product sales to be high while manufacturing products at the best possible quality and low costs. Hence, an overriding consideration throughout all design and development activities is the improvement in efficiency of the process.
- *Standards*: On top of the three main drivers (market, technological and commercial) identified by Clark and Fujimoto (1991), Catalano et al. (2007)

acknowledge that standards constrain the development of vehicle design. For example ISO 612:1978 guides the size and volume of road vehicles.

3.3 Styling design process

Within the automotive design and development process, vehicle styling design is outlined as the stage concerned with the development of aesthetic qualities of a vehicle (Clements and Porter, 2007). This section describes the steps taken by styling design teams in order to generate a vehicle design of such a level that it can be delivered to engineering/detailed design stages. It also shows the inputs and outputs of each stage along with the specific activities that take place during each stage. As an introduction, context of this stage within the aforementioned general and vehicle design and development models (3.1, 3.2) is now defined along with terminology.

For the purpose of this thesis, the term ‘*styling design*’ refers to the part of the design and development process that deals with conceptual and aesthetic design of vehicle exterior. This process occurs as part of ‘*concept design*’ and ‘*conceptual design*’ as defined by Pugh, and Pahl and Beitz respectively, ‘*concept development*’ as defined by Ulrich and Eppinger (2008) and ‘Product plan’ as defined by Clark and Fujimoto (1991).

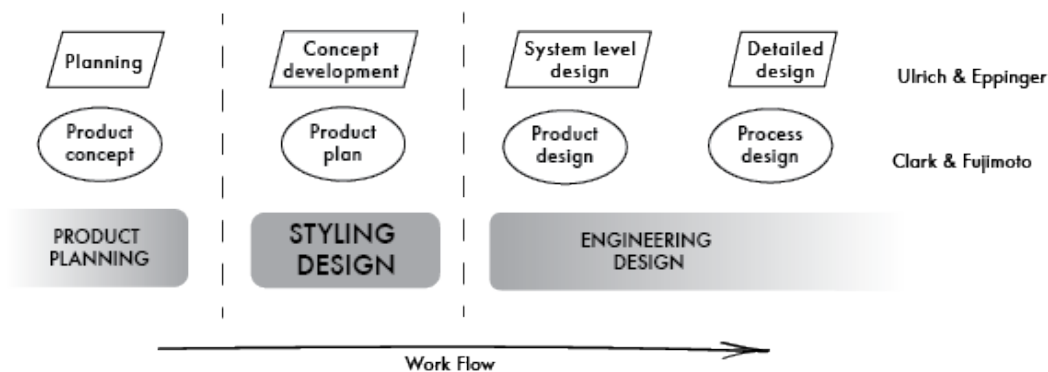


Figure 16 Styling design in the context of previously discussed design and development process models

Figure 16 shows where the styling design process occurs in the aforementioned general and vehicle design and development process models. This is not to say that aesthetics are not considered throughout the other stages of the design and development process. This simply highlights the point at which aesthetics are created.

A process model is now presented showing the steps taken by most styling design teams (Figure 18). It draws from accounts found in literature and interviews with industry educators and professionals. The individuals interviewed their design credentials and the broad topic of the interviews are summarized in Figure 17. The interviews are included in full as an appendix (Appendix 1), however the two major findings drawn from the interviews are now summarised. The first finding relates to the variable nature of the design process. Particularly that the number of iterations and the length of time taken over iterations at any given stage changes from one project to another. The second major finding was that an essential role of the designer is to be able to communicate designs and design rationale to other stakeholders in order to advance the design process. Furthermore it is noted that this can be particularly challenging.

INTERVIEWEE	EXPERIENCE	INTERVIEW TOPIC
R Ferlazzo	Chief designer Holden, GM Australia	Styling design process
S Gauchi	Lead designer, Colour and Trim dept. Holden, GM Australia	Interior styling design process
G E Pepall	Manager of international automotive design consultancy IAD	Styling design process
N Hull	Transportation design course director Coventry University, Associate Editor at Car Design News Ltd	Features in vehicle appearance
M Weaver	Project leader Nissan Design Europe	Styling design process, tools used
C Pollard	Intern at Jaguar Land Rover design UK	Styling design process, tools used
M Richardson	Senior Lecturer transportation design Monash University, Australia. Previously lead designer Ford Australia	Overall auto design process, evaluation techniques, relationship with other dept.s
P Elliot	Lecturer in transportation design Monash University Australia, Design manager Ford Australia	Overall auto design process, evaluation techniques relationship with other dept.s
I Fridman	Lecturer in Industrial design Monash University, Australia, Previously surface modeller Holden, GM Australia	Design process, discussion of manipulation and definition of features

Figure 17 Summary of interviews conducted with industry and educators in styling design

The main stages in the styling design process are shown in Figure 18. These are discussed in the following sections (3.3.1 - 3.3.6) and the outputs of each stage are

identified. The model comprises four major stages: Ideation, Realization, Refinement and Scale model which are now discussed.

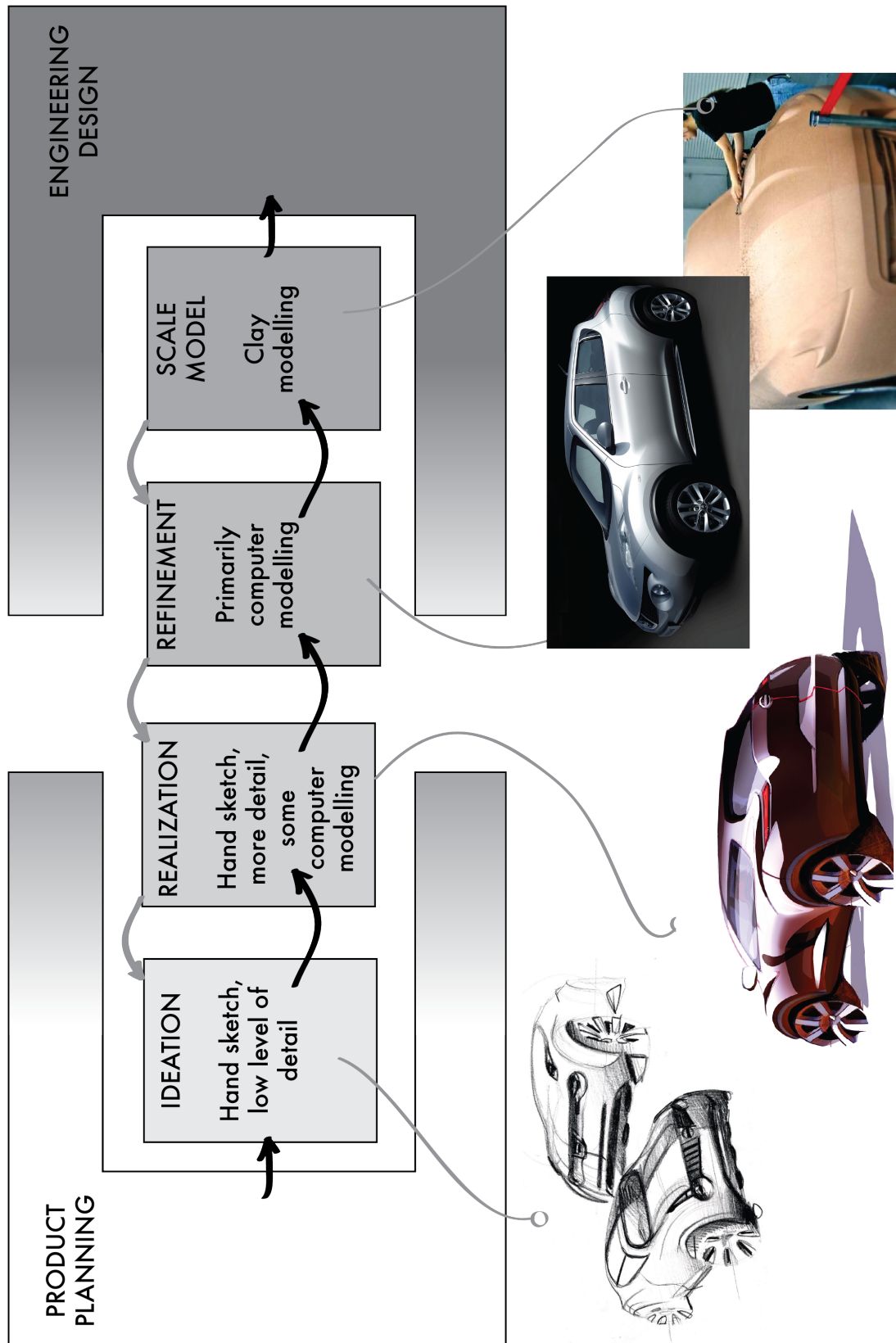


Figure 18 Vehicle styling design process

From discussion with designers, it is apparent that styling design teams do not only work through the presented process when generating designs for ‘ground-up’ mass production vehicles. Styling teams work on concept cars of varying levels of feasibility and development, both to generate publicity and gauge consumer reaction to future designs. Additionally design teams may also work on ‘refresh’ designs where limited aspects of a vehicle are re-designed to promote newer versions of a vehicle. While these alternative projects may not use the complete process described, it can be stated that the model of styling workflow presented here is followed either in full, or in part, depending on the type of design being produced.

3.3.1 Product planning

Figure 18 represents the styling process to produce a complete vehicle. There is a certain amount of design work associated with product planning in terms of generating “Blue-Sky” concepts and other promotional designs.

The product planning stage is the point where designers link to marketing research, management and engineering research and development. The product planning process generates information such as vehicle capacity, target market, and vehicle segment. It can also clarify technical constraints such as vehicle platform, transmission and drivetrain.

Planning output: design brief and specification, sometimes delivered to design teams independently so as not to “blinker” design teams.

3.3.2 Ideation

Ideation represents the process of generating initial design concepts. Designers often use sketching as a tool to ‘bring into focus hazy or fuzzy ideas, in other words they use sketching and other imagery to try to visualize the vehicle. At this stage sketching is not used to convey pre-existing ideas but to explore possible solutions (Tovey et al., 2003). Designers use a wide range of visual imagery to gain inspiration and reference in their designs from which the form of the vehicle gradually begins to take shape.

Ideation output: Sketches in 2D communicating low levels of dimensional and proportional accuracy (Figure 19).

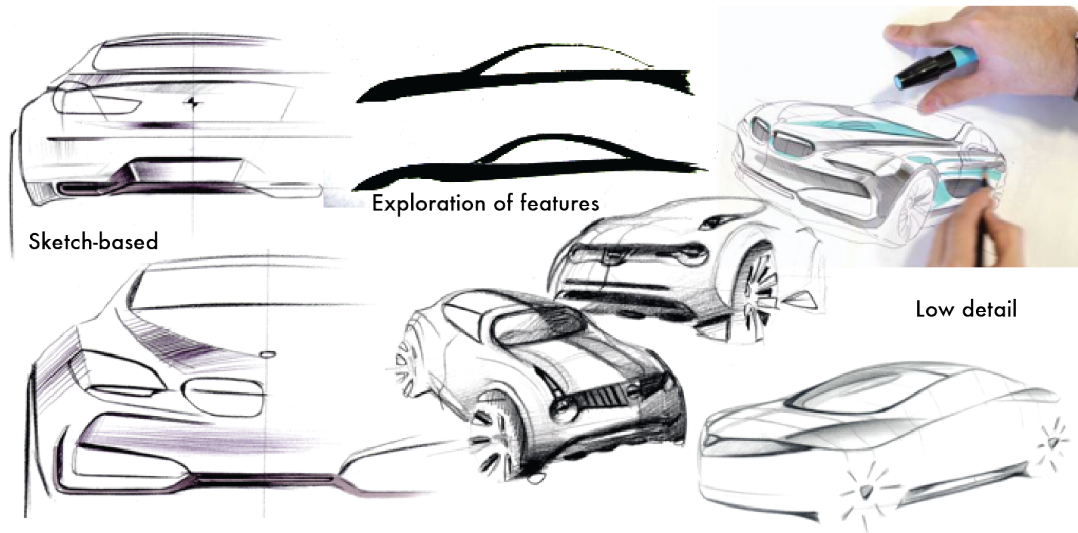


Figure 19 Examples of output from ideation stages

3.3.3 Realization

The realization stage can still be classed as a form of concept generation. Ideation sketches and design themes are further developed into the complete vehicle concepts (Figure 20). A large number of concepts at various stages are produced using sketching and 3D digital modelling tools. The level of accuracy is still low.

Realization output: A range of full/complete vehicle concepts at low levels of accuracy in sketch or 3D digital model.

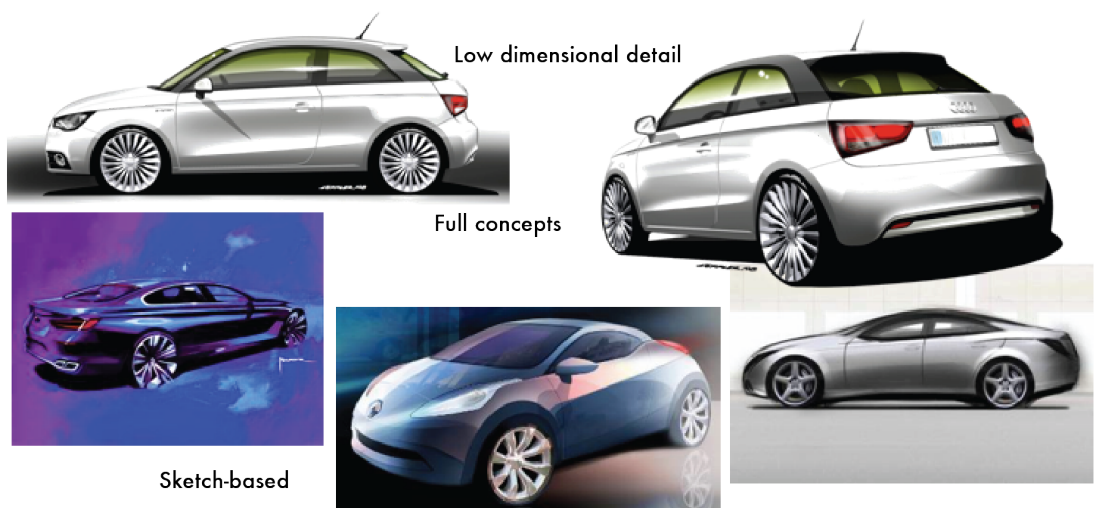


Figure 20 Examples of output from the realization stage

3.3.4 Refinement

The refinement stage consists of further development ideas. A range of ideas are evaluated and further developed, using increasing levels of accuracy and definition. Work at this stage is done predominantly using 3D digital modelling and rendering software. Highly realistic renderings can be generated to create photograph-like views of concepts for evaluation. In some projects smaller scale (1:2.5) physical models are sometimes used (Thomke, 2001). Tape drawing techniques (using sticky tape to draw designs on a wall at 1:1) are also used in some design projects/processes to begin to view designs at full scale.

Refinement output: 3D digital models, high level of accuracy and detail including realistic scene renderings (Figure 21).

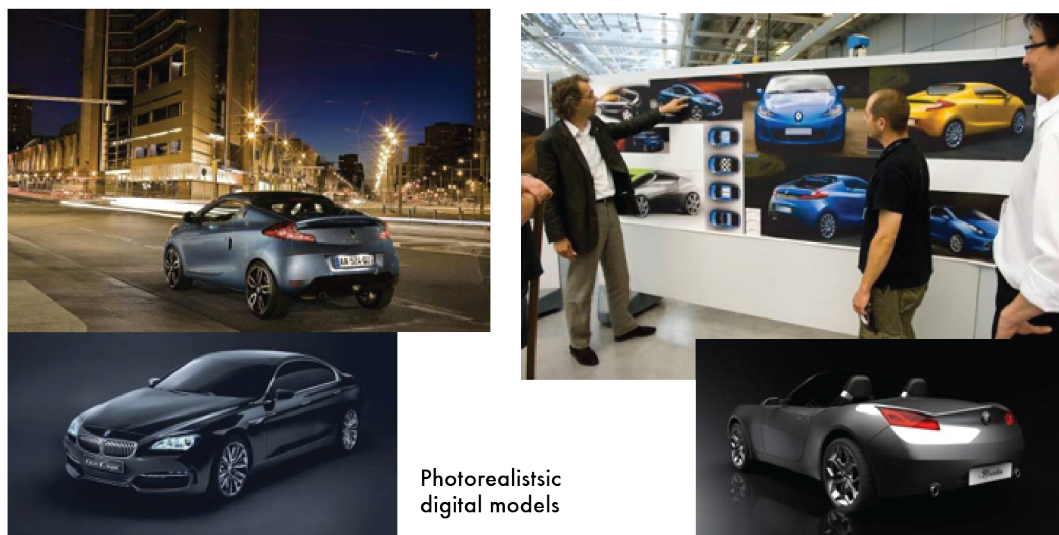


Figure 21 Examples of output from refinement stage

3.3.5 Physical model

The refinement stage is where a small number of the proposed realised designs are modelled at 1:1 scale in clay (Figure 22). Physical and digital models are then refined and reviewed. Depending on the type of project or size of company, a number of proposals may be modelled at full scale in clay or, conversely, not modelled at all.

Physical model output: A finalized full-scale physical model as well as high quality and accuracy renderings of the 3D digital model.



Figure 22 Examples of physical models and images of full-scale model evaluation

3.3.6 “Hand- Over” engineering design

On approval of final designs, the full-scale model is then “scanned” to re-generate digital surface models and the design is officially handed over to engineering design departments. Where previously vehicle manufacturers adopted an “over the wall” design process (Clark and Fujimoto, 1991, Thomke, 2001, Sobek et al., 1999), more companies are now moving to concurrent engineering processes (Holbrook, 1986). As a result there is a need to frequently discuss styling with stakeholders outside of the styling design team such as engineering and marketing.

3.3.7 Evaluation of appearance

Throughout the discussion of the styling design process as well as the generic design and development process, evaluation is shown as the mechanism by which designs progress/evolve into the final form. From interviews with designers (Appendix 1) it is shown that evaluation occurs on a number of different levels.

These range from almost ‘subconscious’/internal evaluation during ideation sketching or refinement and realization while designers work alone, or through informal discussion with group managers. More formal evaluation occurs during discussion with other stakeholders such as engineering and marketing departments. These often follow the form of individual designers or representatives of a design group ‘pitching’ their designs to design managers, senior designers and other stakeholders. During

itches, designers present visual material from given stages of the process 3.3.2 - 3.3.5 representing their design proposals while extolling the virtues of designs and how they fulfil requirements.

While the overall visual impression of the vehicle forms the focus during the styling process and thus criteria for evaluation, inputting factors that drive the overall vehicle design and development process (prices, manufacture, aerodynamics, costs and standards discussed in 3.2.1 - 3.2.3 also form essential requirements evaluated. These inputting factors are largely objective and thus the degree to which designs fulfil them is easily assessed and hence communicated and reasoned upon. Conversely the appearance or aesthetic properties of a vehicle is far more subjective to evaluate. Due to this subjective nature, designers base decisions relating to aesthetic properties on personal perception and opinion. The ability to make such judgments is developed through training and further developed through experience gained as a practicing designer. As such the rationale behind said judgments can be difficult to communicate with the same degree of authority and fluency as objective requirements. Thus the pivotal role of evaluation in the development of styling in conjunction with the difficulties in reasoning on/about appearance due to subjectivity, presents an area of styling design in with potential to be improved through research.

3.4 Support for the styling design process

Academic research and existing support for the styling design process is reviewed here with respect to the four major activities of styling design (3.3.2 - 3.3.5) previously discussed.

3.4.1 Support for the ideation stage

Due to the nature of this type of activity research can be placed broadly into two categories. The first is research into tools for generating the widest possible range of ideas, also described as more exhaustive mapping of solution spaces. The second area researches the way designers use sketching to gain inspiration and visualize ideas.

Generative tools

Support for concept generation during ideation has focused extensively on the use of shape grammars. Shape grammars are described as a set of shape transformation rules that can be applied successively to evolve an initial shape into a potential design. They originated as an architectural tool (Stiny, 1980) to generate geometric patterns that conform to specific styles of building, (specifically Palladio villas, Chinese lattices and the prairie homes of Frank Lloyd Wright).

In terms of vehicle design research, by Cagan et al. investigate the use of shape grammars in generating vehicle (and motorcycle) designs that conform to an established perception of brand image. In particular Pugliese and Cagan (2002) examine Harley-Davidson motorcycles to identify ‘critical visual elements that establish the core of the Harley brand’. Based on these core elements they develop a set of shape grammar rules that can be used to generate simplified profile designs of motorcycles. By adjusting parameters used in transformations a set of differing proposals were generated. A group of Harley Davidson enthusiasts were then surveyed as to which of the designs best encapsulated the Harley brand image. Results from this survey then gave feedback as to which parameters and features define the ‘core elements’ previously identified.

In a similar vein, McCormack and Cagan (2004) explored the use of shape grammars to capture brand identity of Buick cars. A survey of the front view of Buicks over the years was conducted and features such as grille badge and headlights were categorized by the years in which they were similar. A shape grammar was then generated to model the key features based on the eras of vehicle in which they feature. This then facilitated generation of design proposals by adjusting parameters for shape transformations. As well as adjusting parameters purely experimentally, the derivation of the grammar by categorizing features by era, affords the designer the ability to create design solutions that combine styles from different eras.

Osborn et al. (2006) applied a similar methodology developing a shape grammar to explore designs of crossover vehicles. They also develop the procedure for shape grammar generation (Osborn et al., 2008) with the aim of being less subjective. Rather than base parameters on surveys of existing products by designers, they employ statistical component analysis to derive parameters mathematically.

Research into shape grammars as a concept generation tool has also been carried out (Chau et al., 2004) to attempt to derive a simplified grammar through the use of algebraic methods, and subsequently testing it by generating profiles for Coca-Cola bottle designs. Chen et al. (2004) extend this to research the generation of 3D objects. The grammar was used to model a range of personal care (shampoo and shower gel) bottles. It revolved around using some basic rules to form the plan/base shape of the product, with subsequent rules to extrude the shape upwards in the third dimension. The grammar successfully captured elements characteristic of certain brand and was used to generate new designs in the style of these brands.

There are a number of other studies that research generative tools similar to shape grammars. Smyth and Wallace (2000) developed a method for developing designs through computer generation of concepts. The method draws an analogy with biological evolution. A genotype or initial design is selected while a parameter in which to change it is also chosen. A number of variations were generated, subsequently the user may then select a variant to develop further using the same or different parameter. It is suggested that the way a form evolves can be recorded and then applied to other forms in order that they may be styled in the same way.

Yannou et al. (2008b) developed a similar tool using interactive genetic algorithms that allow designers to qualitatively develop designs while still maintaining detailed mathematical knowledge of the curves they are adjusting. Fourier series are used to model the silhouettes of vehicles. This tool also gives the designer the opportunity to 'cross' designs with each other.

Weifeng and Jianghong (2006) developed a tool to generate a variety of concepts based on constraints that drive the shape of vehicle bonnets/hoods. The profile curve of the bonnet was defined by constraints of aerodynamics, engine position, height and length. This then allowed for the development of matrices that could be used to plot a variety of profiles which were then surveyed as to which was the most aesthetically pleasing.

Most recently Lee and Tang (2009) have extended research into shape grammars to include evolutionary computing (use of genetic algorithms to optimise designs). They integrated the two processes with the aim of using shape grammars to provide innovative solutions while retaining stylistic consistency, and evolutionary computing

to guide the generation of concepts. During the research they generated a number of 3D concepts for cameras. The initial generation used shape grammars to generate a selection of random designs. Designers then selected preferred designs and parameters with which to evolve designs, creating further ranges of concepts from which to gather inspiration. In this research, evolutionary computing was introduced to provide a simpler and easier way for designers to guide concepts in order to explore desired solution spaces.

Critique of current approaches

Shape grammars have been shown to be a valid method for generating a wide range of concepts. However, the concepts generated in Pugliese and Cagan (2002) and McCormack and Cagan (2004) are highly simplified and only refer to one view (2D) raising some question as to how useful they are to designers. This is acknowledged by Karjalainen (Karjalainen, 2004) stating that the concepts generated contain minimal information required to communicate with consumers.

Chen et al. (2004) are more successful in the development of aesthetically viable concepts as they are 3D models. It should be noted that these concepts are of comparatively simple forms. Thus it is possible to suggest that shape grammar techniques become far less relevant as the complexity of the form being developed increases.

While Cagan's work, (Pugliese and Cagan, 2002) and (McCormack et al., 2004) report the ability to capture brand, the grammar generation procedures are reliant on designers to specify features which are used as parameters to generate the grammar. As a result the concepts generated are as subjective as those that could be generated by designers alone.

Osborn et al. (2006) address this, attempting to remove subjectivity by deriving parameters statistically. This method does still include a degree of subjectivity as a number of features must still be initially identified by the designer.

A further issue with shape grammars is the willingness of designers to use them extensively. From interviews with automotive styling designers, it was found that they draw inspiration for design proposals from sources far more wide ranging and esoteric such as films, fashion, music and personal experience. A range of concepts generated

by shape grammars are thought to be too scientific for the nature of the initial ideation phase. It is also recognized that the designers are proud of their traditional skill set and may also reject concepts developed by computer on grounds that it nullifies such skills in attempting to replace them.

In summary, it is seen that shape grammars are a valid tool to generate a wide range of simple product concepts in an exhaustive and objective way. However, their ability to capture brand is questionable, as they still require the subjective eye of the designer to specify elements and features, which may or may not be key to brand.

Sketching in Ideation

The role of sketching within the ideation process has been documented by Tovey (2003) who shows that sketching in the ideation phase is done not to communicate an existing idea to another individual, but to ‘give external definition to an imagined, or only half imagined, suggestion for a design form’. This activity is also referred to as visual thinking. Figure 23 derived from Buxton (2007) describes this concept in more detail. It shows that a designer represents knowledge or an idea as part of a sketch. Having visualized the sketch externally the designer can then read/absorb new knowledge from it, generating further ideas to add to the sketch.

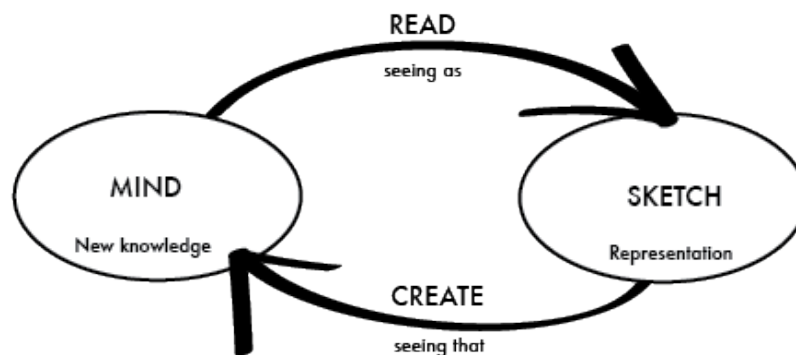


Figure 23 How designers use sketching to generate new ideas

Buxton (2007) states that one of the key reasons that this kind of iteration can occur is through ambiguity in the sketches. Ambiguity means that the sketch or form created can be interpreted in different ways by designers and that different interpretations form new relationships within the sketch.

Ambiguity in sketches inspiring designers has been used as an input in computational generative tools. Prats et al. (2006) have identified that ambiguity in sketches is ‘central to creativity’ (observations on ambiguity). By investigating the way a number of designers went about sketching a range ideas, it was possible to identify a number of types of transformation that designers use during the sketching/ideation process. These transformations form the basis of the generative computational tool. It is suggested that designers use the tool as an additional third stage in the model of sketching as a visual dialogue shown in Figure 23.

3.4.2 Support for idea realization

A number of issues have been identified with the current styling design process (Barone, 2004, Giannini et al., 2006, Podehl, 2002). In particular the progression from 2D sketch design to 3D digital models has been shown to be highly problematic. In the most obvious instance it is somewhat laborious to have to recreate the same design but using a different medium. Barone (2004) identifies four key issues with the use of 3D modelling software. These concern complexity, communication, proficiency and evolution of software discussed further in Table 1.

Complexity	Design software can be complex to operate
Communication	Due to complexity, software is often operated by technicians or digital sculptors requiring designers to communicate intentions to their personnel
Proficiency	A designers capability in a given software can subconsciously limit their creative output
Evolution	Constant updates and evolution in software and capabilities result in a requirement to spend increasing amounts of time getting to grips with developments

Table 1 summary of issues associated with the use of 3D modelling software

Based on these problems relating to the use of 3D modelling software, there has been work to encourage earlier digitization of designs while maintaining traditional

‘designer-friendly’ interfaces. One example of research into this type of interface is digital tape drawing, a method previously used when communicating profile sketches at full scale (Figure 24).

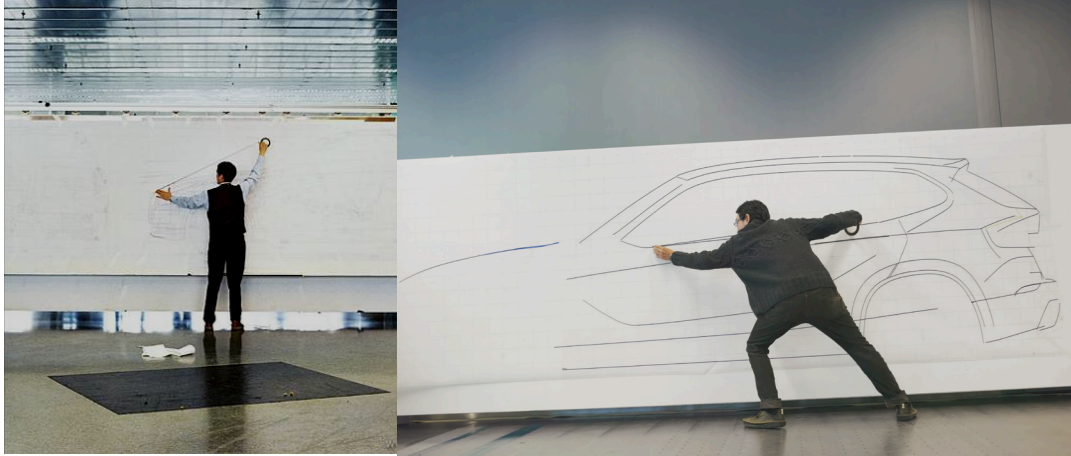


Figure 24 Tape Drawing

Work by Balakrishnan et al. (1999) firstly developed an interface that mimics actions of tape drawing but creates a digital drawing. It uses six degree of freedom trackers held in each hand in conjunction with a digital projector and an 8ft x 6ft display screen (Balakrishnan et al., 1999).

The tool was developed further to incorporate a 3D capability (Grossman et al., 2001). By giving the designer a number of planes to draw curves on, a simple 3D wireframe model could be generated.

Through analysis of the design process Bae and Kijima (2003) found the following three key guidelines to improve the use of 3D modelling software in the styling process:

1. Vector based digital sketching for ideation stages.
2. A ‘trans-dimension styling step’ that would allow ideas to be imported into a 3D environment and modified rather than re-created.
3. Avoidance of engineering CAD tools in favour of styling specific software. The reasons for this guideline are that the models generated are only evaluated aesthetically, hence there is no requirement for the accuracy and capability available in engineering CAD software.

Fleisch et al. (2004) extend this work and propose a ‘virtual table’ on which designers can use pen-based or tape drawing tools in conjunction with optical trackers to draw in a virtual reality environment. As with digital tape drawing, 3D models are created by constructing curves in a number of different 2D planes.

Kara et al. (2006) and Kara and Shimada (2008) investigate the use of pen based inputs in conjunction with 3D drawing templates. This research aims to use 2D hand sketches to provide detail and development to simple 3D templates. Key ‘nodes’ are marked on the template and the corresponding nodes marked on 2D perspective sketches. The template can then be manipulated and altered into the form represented in the sketch. The developed system then uses the pen-based interface to allow the designer to deform the template manually and reinforce styling lines by sketching them directly onto the 3D model.

Critique of support for realization

As with all techniques available to designers, different design teams use differing tools in differing workflows. Through interviews with industry professionals, it was found that the use of tape drawing has declined with the availability of better digital sketch and surfacing software in conjunction with large high definition digital displays (Figure 25).

Digital tape drawing used in conjunction with large displays gives designers the ability to use a traditional interface to draw digitally and move into 3D earlier in the design process while also providing better information management. Despite these innovations industrial uptake of digital tape drawing has been limited likely due to developments in other visualization technology and modelling software. Thus what is seen more and more in contemporary vehicle styling design workflow is the use of digital sketching interfaces and software (Figure 26). Presently this does not encourage earlier generation of 3D models, however it does maintain a traditional interface in the form of a pen and tablet and also improve management of data/designs.

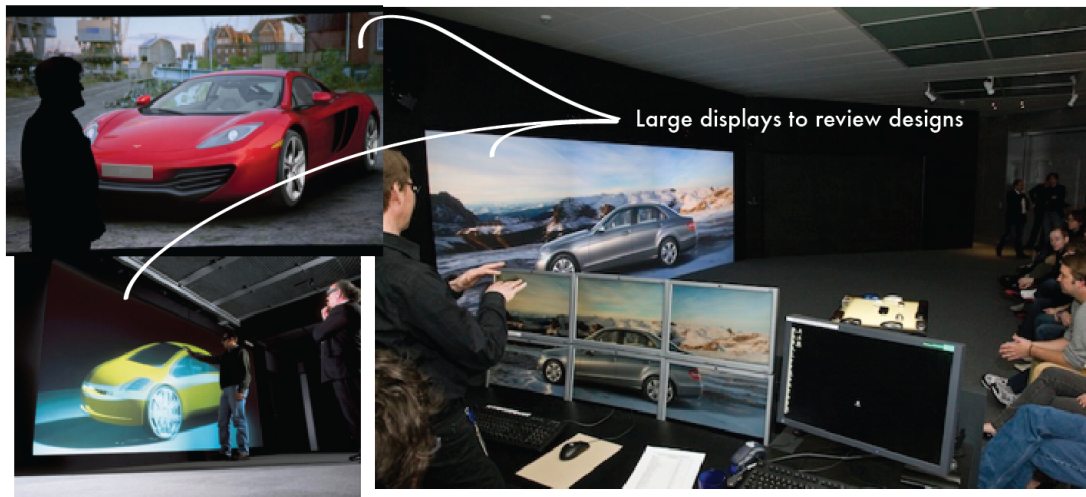


Figure 25 Examples of the use of large displays to review digital models at full-scale

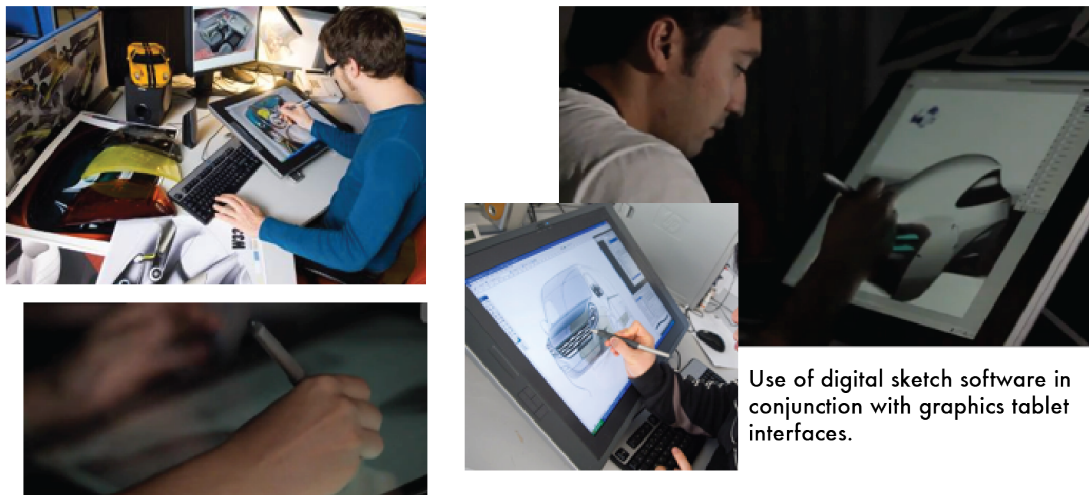


Figure 26 Designers using digital sketch software

Based on the bodies of research reviewed in this section, it can be argued that much of the development work relates to software and software interfaces. Hence research that could be conducted to further improve these aspects of the styling process would likely be manifested in developments in software design and digital display technology, both outside the scope of this thesis.

3.4.3 Support for idea refinement

The major research undertaken in development of tools to aid in the refinement stages of vehicle styling has been conducted as part of the FIORES and FIORES - II European projects. The main aim of these projects was to improve working procedures

and computer aided tools for modelling shapes (Giannini and Monti, 2002). Fulfilling this aim was approached by researching three areas which are now discussed.

Giannini and Monti identify the three key areas in which research was conducted to attempt to: define vocabulary used in styling, map relationships between geometry and styling/aesthetic character, and mathematically extract geometry to be optimized with respect to aesthetic character. These are now discussed further.

Vocabulary

The first area of research aimed to define a vocabulary used in aesthetic design. Through interviews with professionals and analysis of the styling workflow, Giannini and Monti define the three categories of language/vocabulary used in discussion with different groups during styling design (Figure 27). These categories were defined as Emotional, Visual and Surfacing and Geometric used in relation to different activities and by different stakeholders in the styling workflow

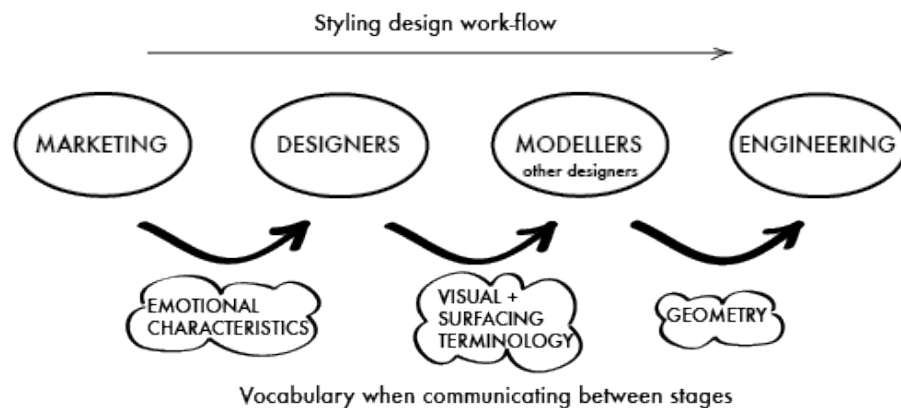


Figure 27 Use of different terminology and vocabulary between stages of styling design process adapted from Giannini and Monti 2002

Mapping

The second area of research aimed to map aesthetic and styling character on to geometric entities. Podehl (2002) maps the geometric operations/modifications that result from stylists' and modellers' terminology. Cheutet et al. (2005) identify that to use industry standard surface modelling software to its full potential requires some knowledge of mathematical language 'unsuited to the way designers are used to specifying shape'. Thus the primary aim of this part of the FIORES projects was to develop a method of modelling high level surfaces, or free-form features, which

allowed for direct manipulation of surfaces through intuitive parameters, rather than mathematical language. Figure 28 taken from (Cheutet et al., 2005) details what is meant by the term ‘free form feature’ by highlighting its difference from a classic engineering feature. That is the inclusion of geometric elements such as points and lines as well as higher degree of surface continuity.

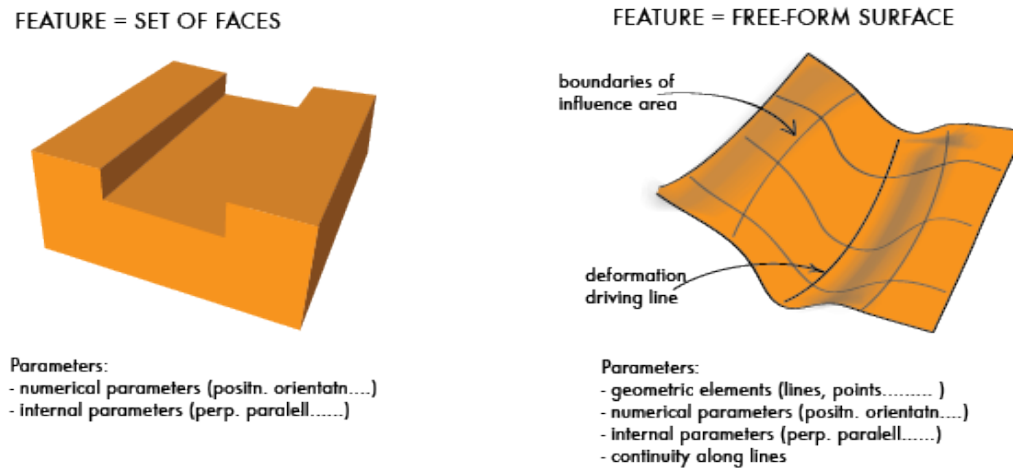


Figure 28 Illustration of 'free-form features' compared with more basic features adapted from Cheutet et al. 2005

The first step in doing this was to develop a free-form feature taxonomy. In other words, a generic system to classify features by their geometric properties. Having developed a generic feature taxonomy it was then possible to use a ‘deformation engine’ to adjust features in terms of shapes and features themselves rather than trying to obtain desired shapes/features using simpler geometric tools.

The free form feature taxonomy was developed by Giannini et al. (2006) where the taxonomy was combined with the styling terminology developed by Podehl (2002). The resulting software allowed designers to deform and adjust free form features using the type of vocabulary that would be used when discussing the adjustment of models with modellers. Giannini et al. (2006) develop the taxonomy further by mapping aesthetic character to free form features. This then facilitated ‘CBR’ (*character based recognition*) where designers could assess and compare aesthetic character of the features that had been deformed/adjusted.

Algorithms

Finally the third area of research aimed to create algorithms and software to extract aesthetic shape properties and also optimise and adjust designs with respect to aesthetics (Catalano et al. (2007)). This research developed an ontology of vehicle categories and specific parts, which led to the development of a further ontology of typical surface treatments applied to specific parts in order to ‘style’ the car. Generating this formal classification of vehicle parts and styling features allowed for the vehicles to be modified and adjusted intuitively while maintaining high-level free form surfacing. The vehicle part ontology was also integrated with the character based recognition capability (Giannini et al., 2006), forming a geometric assessment and comparison platform.

A number of other research studies into the classification of free form features have been conducted with the aim of making them easier to retrieve and re-use in further designs. Hernadvolgyi et al. (2004) construct an ontology to do this based on the geometric context within which a part exists. The example used to demonstrate this is the hood/bonnet panel of a car. At each of its edges, a hood panel is linked to, and hence shares a certain amount of geometry with, other panels such as the fenders and bumper/fascia. This affords easier retrieval of designs, thus it is argued that this research contributes on a knowledge management level. This research also provides a more direct input/application in refinement design as it would allow contextually related features to be edited and viewed along with a specific feature being edited.

Nyirenda et al. (2006) create a free form feature taxonomy in the same manner as Cheutet et al. (2005), based on initially classifying ‘feature class’ and then classifying the feature further using a set of generic specification attributes.

Attene et al. (2009) developed a ‘ShapeAnnotator’ which aimed to decompose digital model surfaces into parts and annotate them based on an ontology. The example ontology described here was based on human anatomy, classifying body parts of digital figures/avatars. This ontology provided the information to allow surface segments to be tagged semantically. The goal is to be able to annotate 3D models semantically and automatically based on ontological data.

Chung and Lee (2007) present a more direct tool that could be used to classify the overall form of digital models. The method presented is based on the concept of ‘eidetic reduction’, which revolves around simplifying the form of products (in this case mobile phones) into a hexahedron with edges filleted with varying sized radii. This method proposes a more systematic way to investigate and compare the overall form of design.

Wei (2006) developed a design tool similar to the CBR tool (Giannini et al., 2006). The CBID (*case based industrial design tool*) allows designers to generate design features in a software environment which can recognize the type of feature being designed and retrieve similar features. The aim of this software was to facilitate easier and quicker feature generation and refinement.

Critique of support for refinement

Much of the research conducted into refinement stages of styling design proposes tools that aim to improve information management. As with tools assisting in realization stages, many of the tools are software based. The proposed tools aim to provide a better management of features through enabling easier identification of aesthetic traits for future recall and easier adjustment of features. Although tools presented achieve their aims they still require a degree of subjective judgement by designers in defining aesthetic traits and the review of implemented adjustments of features.

3.5 Concluding remarks

The first part of this chapter reviews the general product design and development process subsequently focusing on the styling design process. This review is used to provide an understanding of the styling design process which this thesis aims to improve. The review highlights the importance of evaluation in the design process in driving the creation and development of designs and thus the eventual appearance of products. It also highlights the subjectivity and hence difficulty in evaluating aesthetic properties of appearance compared with evaluating more objective factors such as those relating to marketing, technology and commercial aspects. This difficulty in communication is also echoed in interviews with practicing designers.

The second part of the chapter considers literature reporting approaches to improve the styling design process and the development of supporting tools. There is an overriding trend in the development and improvement of software or software based environments that aims to make the tools used by designers and other stakeholders simpler to use thus improving the efficiency of the process but do not address the subjectivity in evaluation of appearance. It follows that further study based on such developments is rooted in the improvement of software and associated technology.

In terms of the earlier stages of the design process, many of the proposed improvements also incorporate software. These ideas predominantly address more exhaustive generation of ideas or the creation of designs including key features or variations on them. However, the majority of these solutions still require designers to make key judgements on subjective aspects such as features characteristic of a particular brand. Some further studies have been conducted in order to address this in reference to concept generation (Orsborn et al., 2008, Orsborn et al., 2006).

Thus the key contribution of this chapter is the identification of a gap in research to improve the styling design process surrounding the subjectivity in the evaluation of aesthetic properties that constitute appearance. To explore this further, the following chapter explores factors that influence product appearance including consumer reaction and response to appearance and its strategic use to generate appeal.

4 FACTORS INFLUENCING PRODUCT APPEARANCE

Where the previous chapter addresses the background relating directly to the process of design, this chapter reviews the literature that is associated with factors that influence the creation and evaluation of product appearance.

The chapter begins by reviewing the concepts behind consumer response to appearance. This ‘phenomenon’ may be said to be the main driver for the in-depth consideration of product’s appearance during design, thus an understanding of the theory of consumer response is central to the research in this thesis. Following discussion of this concept, its acknowledgement in design research is next covered (4.2). Section 4.3 considers research into design methods that specifically consider appearance and aim to use it to influence consumer response.

Having discussed the underlying concepts that explain the use of appearance, specific factors/uses of appearance to gain competitive advantage are discussed and particularly those associated with visual branding.

4.1 Consumer response

This section considers research conducted into aesthetics in their own right, and in particular, perceptions of visual forms and how they influence appraisal of said forms. Section 4.1.1 presents research into the use of aesthetic properties as a form of communication while 4.1.2 reviews consumer reaction and perception to such properties.

4.1.1 Design as a form of communication

Sections 1 and 3.4 identify that styling or purposeful manipulation of aesthetic properties is undertaken in order to enhance positive consumer response to a product. In other words, this proposes that at some level designers are influencing the visual

properties of a product such that they will signify or communicate information to the consumer.

Some forms of design communicate with consumers more explicitly than others (Crilly et al., 2008a, Crilly et al., 2008b). For example, print designers, such as graphic and advertising designers, can obviously be seen to be communicating with consumer via mass media such as television, internet and print media. In a similar way architects are said to communicate through the scale of their designs and exposure of them to a mass audience. Product designers can be said to communicate through mass media through the physical form of mass produced products.

Zeisel (1980) states that one of the main objectives of designers is to control the behavioural effects of the design decisions they make. Based on this Crilly et al (2008a) propose that if the intention of designing something is that it should elicit some response in consumers, the product in question may be treated as communicative media.

A number of studies have created a concurring model to define the mode of communication between designers and consumers via the medium of product form (Monö, 1997, Schramm, 1961, Shannon, 1993) (Figure 29). In this model it can be seen that the designer or company may viewed as a source of information that uses products to transmit information/intentions. These are then received by consumers who subsequently form judgments (ideally) based on said intentions.



Figure 29 Model of product form as medium for communication

Schramm (1961) adds to this model suggesting that experiences of the designer/manufacturer and consumer must overlap, arguing that designers and

consumers must overlap in order for some point of reference to base communication on.

4.1.2 Consumer perception and reaction

Section 4.1.1 shows that designers, at some level, communicate with consumers. This introduces the first stage in the process of aesthetic design, eliciting consumer response. In terms of the above model (Figure 29) the stage of the consumer as the receiver is explored. In order to further understand the influence of aesthetics on consumers, the topic of consumer response is considered in three parts, processing, perception and reaction.

Processing aesthetics

This processing stage refers to the initial computation of visual information that first enters the brain. Bloch (1995) discusses the two basic forms of cognitive response to visual information. When discussing gestalt psychology Katz (1950) states that products are initially seen holistically. In other words, the human brain first processes the overall form and then, assuming that the viewer is suitably interested and stimulated by what he or she sees, further smaller details are then processed. Similarly Baxter (1995) discusses processing by global precedence. This states that the consumer first sees things as a whole and that this then defines how much further detail of the object is considered based on interest and attentiveness.

Mono (1997) defines the idea of gestalt as ‘an arrangement of parts which appears and functions as a whole that is more than the sum of its parts’, hence suggesting that a product is perceived as a whole rather than its constituent parts. In contrast, Durgee (1988) states that initial reactions to products are formed atomistically. In other words, consumers form initial reactions to products by looking at appealing constituent parts.

Bloch (1995) unifies these opposing theories suggesting that both processes occur sequentially. He argues that consumers initially see things as a ‘whole’ and then if the object evokes interest the consumer views it in more depth seeing all components that create its form. Figure 30 provides an example of Bloch’s unified processing theory. When first viewed it appears to be a diamond and a right-angle triangle within two

blocks. On further processing one sees that that the shapes are represented by small circles and triangles respectively.

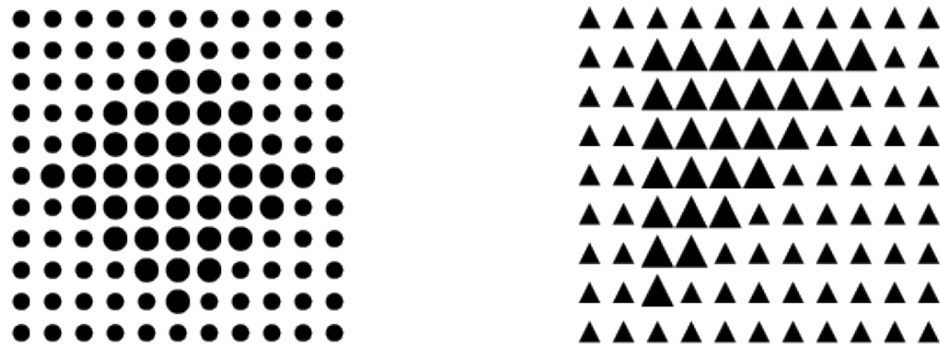


Figure 30 Demonstration of gestalt and atomistic processing

Athavankar (1989) discusses a further type of processing of aesthetic forms, ‘categorization’. This model of processing states that humans have the ability to construct mental categories to allow association of visual information with abstract concepts. Hence when consumers process visual information they analyse details in order to ‘categorise’ what is being seen, facilitating an understanding of it.

Affective/Emotional perception

Much research has been conducted into the way consumers derive emotional or affective responses to products. Table 2 shows the commonly acknowledged model of affective response (Baxter, 1995, Crozier, 1994, Cupchik, 1999, Lewalski, 1988, Norman, 2004). The models presented are all based on the same three stage model shown below, differing slightly in terminology. Table 3 uses Norman’s terminology for response types as it is contended that they are most descriptive of their nature, to provide examples of the three different types of response.

RESEARCH	Affective response stages and terminology used		
	STAGE 1	STAGE 2	STAGE 3
Norman 2004	Visceral	Behavioural	Reflective
Crilly 2004	Aesthetic Impression	Semantic Interpretation	Symbolic Association
Cupchik 1999	Sensory/Aesthetic	Cognitive/Behavioural	Personal/Symbolic
Baxter 1995	Intrinsic	Semantic	Personal/Symbolic
Crozier 1994	Form	Function	Meaning
Lewalski 1988	X-values	Y-values	Z-values

Table 2 Summary of 3-point affective response models

VISCERAL	BEHAVIOURAL	REFLECTIVE
Stage 1	Stage 2	Stage 3
Basic or instinctive reactions to visual form	Response and opinions based on the use of a product	Reactions based on previous experiences of products and the associations they create
Desire linked to seeing a bright red Ferrari, or expensive, illustrious gold jewellery	Dissatisfaction at the difficulty parking the bright red Ferrari, or inconvenience of owning valuable jewellery	Fond memories of once owning a bright red Ferrari, or the way one looked when wearing expensive gold jewellery
IRRATIONAL	RATIONAL	RATIONAL

Table 3 Examples of three types of affective response

Reaction

Desmet (2003) elaborates on these three basic categories of affective response, setting out five categories in which reactions to products may be formed and elicited. These are all formed on the basis of how perceptions of products compare against user expectations. In other words they could be described as a set of five metrics to measure consumer emotional response.

- *Instrumental* – This can be summarized as a judgement as to how well one believes a product would help them to accomplish goals.
- *Aesthetic* – How well a product's form aligns with dispositional likings for certain items or attributes of objects

- *Social* – In response to how a product aligns to users' socially learned standards. Example emotions are admiration and indignation.
- *Surprise* – Relates directly to the product but not to any specific concern. Simply put the ability of a product to surprise users, unexpectedly matching or mismatching with a concern.
- *Interest* – In response to how engaging a product is, in other words, how much it stimulates the user.

Jordan (2000) also presents a set of measures/metrics formalising ways in which perceptions are evaluated to form reactions.

- *Physiological* – Pleasures derived from physical sensations related to using a product such as the appearance of a stylish phone, tactile feel of a handle or even smell of a new pair of shoes.
- *Sociological* – These are evaluations relating to the way products allow or evoke reactions from others. An example is admiration of a new product or feelings of acceptance within a group through ownership of a product.
- *Psychological* – This relates to cognitive demands of using a product. An example might be the ease of achieving desired goals by using a particular computer operating system.
- *Ideological* – This type of pleasure relates to interaction with products that represent beliefs held in regard by the user. For example a consumer may get pleasure from using a bicycle as it is less harmful to the environment than a car.

These factors do not provide any further depth to responses relating directly to aesthetics. They do however illustrate another approach to structuring and categorizing of the ways in which products can elicit emotional response in consumers.

Concluding remarks

This section firstly demonstrates the concept of products as a medium to communicate certain messages to consumers. The section then explains the mechanisms by which this communication is processed, perceived and subsequent emotional response by consumers.

Secondly this section presents research which aims to rationalize the relationship between consumers and appearance. This is done from the perspective of the consumer in that particular types of response are identified/structured. Thus while providing insights on the types of response that can be elicited by designers there is no structuring/rationalization of elements of appearance that may achieve responses.

4.2 Design methods for consumer response

Product appearance has been discussed along with the mechanisms by which they influence consumers. This section features an overview of the literature addressing styling and styling design methods with the intent of eliciting particular response with respect to appearance. This begins with the topic of Kansei engineering, a body of research that considers subjective elements of design such as aesthetics/appearance.

4.2.1 Kansei engineering

Levy et al. (2007) state that the word ‘kansei’ cannot be directly translated into English but define it loosely as the impression a consumer derives from a product. Hence ‘kansei engineering’ includes subjective responses of consumers as a functional requirement in the evaluation of designs. Thus it can be observed that the concept of kansei engineering is a formalised recognition of the inclusion of subjective perceptions within design specification and development. Kansei engineering has been permeated and used successfully in Japanese and eastern industries such as automotive and consumer electronics (Nagamachi, 1999).

Schutte (Schutte and Eklund, 2001, Schutte, 2005) conducted further research into kansei engineering and the way in which the kansei (impression) of consumers may be captured and formalised for use in further design. Thus the studies aim to connect kansei to technical characteristics through identifying correlations between consumer responses represented by adjectives in reference to existing designs.

Lee and Lee (2007) further develop research of this nature conducting a similar study but into the impressions created by designers and evaluated by consumers on an aesthetic level. They identify that adjectives can be overly subjective and only of real

use within countries where the language is native. Designers were asked to create concepts with a kansei represented by a collection of images. Consumers were then presented with the designs and asked to select images which best represented their perceived kansei. The results suggest that evaluation of kansei in this visual sense provides a less subjective correlation between kansei and product form characteristics.

4.2.2 Other approaches

When considering aesthetic design of products, it can be seen that there are two key areas constituent in this concept. Van Breemen and Sudijono (1999) define these two areas as the ‘space’ of shape characteristics and the space of ‘aesthetic’ characteristics. In acknowledging these two spaces, Van Breemen and Sudijono devise an approach to investigating the role of aesthetics in design by mapping between these two spaces (Figure 31). It is shown that mapping shape characteristics of products onto aesthetic characteristics represents an approach of designing aesthetically pleasing objects. It is also shown that mapping from aesthetic characteristics onto shape characteristics provides an understanding of the relationship between shape and aesthetics. It is in this second mapping that Van Breemen and Sudijono investigate measuring aesthetics.

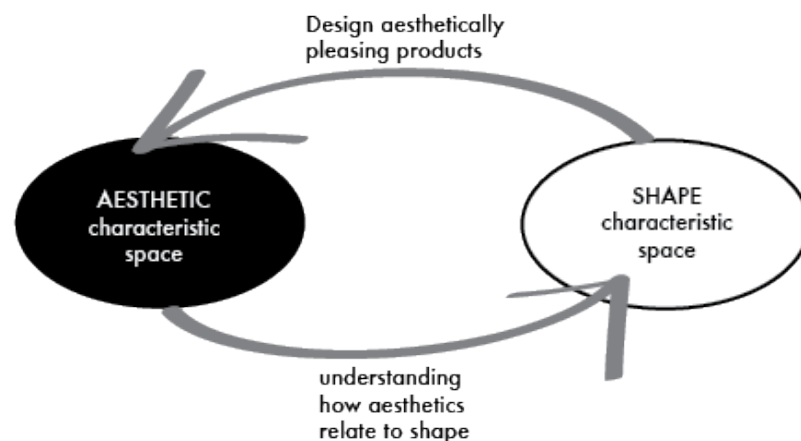


Figure 31 Mapping between aesthetic and shape characteristic spaces

To test this mapping technique an experiment was devised to relate aesthetic characteristic to shape characteristics through a survey where participants were asked to observe a range of products and supply verbal descriptions of shape and aesthetic character. Then by clustering responses it was possible to provide a limited mapping between shape and aesthetic characteristics which could then be applied to further

designs aimed to have a certain aesthetic character. Van Breemen and Sudijono (1999) do acknowledge that these mappings are limited due to the sample of shapes used in the experiment and the subjective nature of verbal descriptions of shape and aesthetic.

McDonagh et al. (2002) attempt to address these limitations proposing three approaches: 'product personality profiling' (PPP), 'mood boards' and 'visual product evaluation'. The PPP approach required participants to construct a human personality profile to describe products attempting to elicit a lot more information regarding the overall perception of products such as social values attributed to products.

The second approach required participants to construct 'mood boards', visual imagery which they felt best illustrated the aesthetic characteristics of a product. This method goes beyond linguistic restrictions providing direct inspiration for designers to use, thus reducing subjectivity from linguistic interpretations, but not wholly excluding it.

Acknowledging the effect of visual judgements on purchasing decisions and their growing importance in internet based shopping, the third approach asks participants to respond to a questionnaire based on the type of limited information given to consumers in these shopping environments. Although this method maintains a high level of subjectivity in participant's responses, it does highlight the aesthetic characteristics most appealing to consumers when given limited visual detail in web based shopping environments. Conclusions from these three approaches were that the use of a number of different approaches produce the most informed mappings between aesthetic and shape characteristics.

Desmet (2003) develops a tool to measure emotional responses to products. They propose that by better understanding emotional effects of products on consumers, a better understanding is gained of the relationship between subjective affective response and physical form characteristics. Desmet identifies the shortcomings associated with verbal descriptions of affective responses and also adopts a visual approach. The method adopted (termed PrEmo) shares its approach with another tool (SAM scales) developed by Bradley and Lang (1994). These methods use an illustration of a character to pictorially represent emotions that may be experienced by consumers (Figure 32). It is thought that these cartoon-like representations are far less subjective than verbal descriptions and are also suitable for use through different languages and cultures.

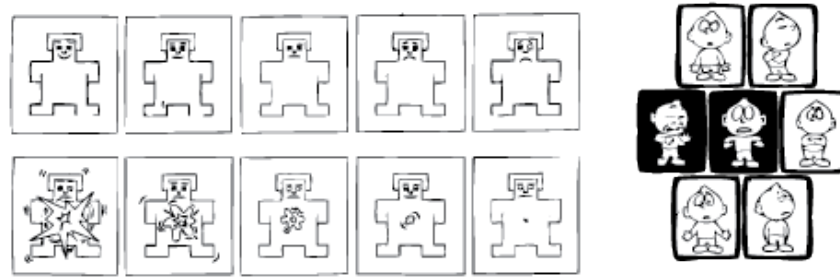


Figure 32 Examples of cartoon illustrations used to represent emotions from SAM scale tools (left), and PrEmo tools (right)

Desmet (2003) uses the PrEmo tool to survey consumer's emotional responses to images of five different vehicles. From the results of this survey it was possible to cluster the vehicles according to the emotional responses they elicit. This provides a graphical mapping between the emotions elicited and design characteristics. This result is different to the previous studies discussed in that it effectively skips mapping shape characteristics to aesthetic characteristics, going straight on to the emotional response experienced by the consumer. This is however still a measurement of aesthetics, rather than mapping between form and aesthetic characteristic/description it aims to measure physical forms by the emotions they elicit.

Warell (2004) proposes another approach to the measurement of aesthetics. Rather than explore different techniques to gather consumer responses to product forms, it is the visual forms themselves that are explored. A single image of a product, such as the cab section of a lorry (truck), has different features on it modified in a number of ways. The variations of the product were then surveyed by potential consumers. The survey asked participants to review images and mark on a seven point Likert scale (rating scale) how much they found images to embody certain adjectives.

The sample surveyed was not deemed large enough (6 participants) to conduct a statistical review of responses. It was concluded that this approach provides the first step towards a theoretical understanding of design 'phenomenon' which could be used to design products to be judged aesthetically.

Chen et al. (2007) present an approach to measure effects of automotive styling features on perceived aesthetic character. This approach is similar to that of Warell (2004) in that it explores responses to a variety of modified products. It applies a

selection of different headlight, grille and vent shapes to a range of ‘de-branded’ vehicles. Participants were then asked to rate the resulting vehicles against bi-polar adjective scales. Results from the study showed that application of certain shaped features encouraged certain interpretations of aesthetic character. It was proposed that these results could guide further designs in aiming to target certain markets. It is, however, also acknowledged that during automotive styling, aesthetic character is addressed/evaluated throughout the entire process. Hence, information relating to fully formed features may provide some guidance for designers, but it is unlikely that these features would be applied directly to designs during early stages of the styling process.

Karjalainen and Warell (2005) investigate the relationship between product aesthetics and brand recognition/perception identifying categories of product features/cues that encourage/enable recognition. The key findings are:

- They define explicit design cues as being precisely definable and consistently used. Examples include features such as logos and badges, or styling lines maintained through a complete product range over a number of years.
- Implicit design cues are far less distinguishable than explicit cues. They are described as a general style or form language. An example presented is of the Porsche brand. Their vehicles do not exhibit distinctive elements such as a grille but rather by a combination of surface treatments.
- Qualitative design cues are described as consistency in of identity and/or coherency of product messages across a product portfolio and/or product generations. An example used is the perception of Volvos as safe and Scandinavian cars.

Warell et al. (2006) further develop the ideas of aesthetic cues to brand by researching emotional responses and relating specifically to aesthetics and branding. Three modes of perception and interpretation of brand identity through product aesthetics are identified.

The first is a ‘recognition’ stage, where product type or brand can be identified by prototypical features. For example a cheese grater’s function can be identified by its grater slots. DeWalt power tools can be identified by their predominantly yellow and

black colour scheme. This stage is somewhat similar to Norman's 'visceral' perception stage in that perceptions are based on the product's visual properties.

There is a 'comprehension' stage where expression of product properties, operation or performance can be identified through visual references. These identifications are more subjective, for example some may identify a large 4x4 vehicle used in an urban environment as a safe vehicle. Others may identify it as being wasteful and damaging to the environment.

The last mode of identification is referred to as 'association'. In this mode, perceptions of brand and product heritage, values and origins are identified through symbolic signs such as logo or typical brand features. Judgements through this mode are highly subjective as they are based on previous experience or knowledge of the brand. Perceptions of brand formed through comprehension and association modes are similar to the reflective affective response (4.1.2) in that they are highly subjective to the consumer.

Concluding remarks

This section reports a range of different approaches that attempt to link structure aesthetic and shape characteristics with consumer response. These studies provide a number of strategies which can be used to give designers an understanding of the potential impact of appearance on consumer response. While these can be of value there is still a relatively high degree of subjectivity in results. This is shown to be reduced by avoiding association with linguistics when assessing features in favour of visual material but not removed.

It is contended that much of the subjectivity that is inherent in these methods is due to their focus on aesthetic character and its interpretation by consumers. Notable studies by Karjalainen and Warell address brand which is far easier to define to/for consumers thus resulting insights are significantly more objective than those concerning aesthetic character.

4.3 Strategic use of appearance to gain competitive advantage

In modern society, aesthetic sensibilities are relevant to all products, regardless of their function (Bloch, 1995, Karjalainen and Snelders, 2010). When given the choice between two products, equal in price and function, target consumers buy the one they consider to be more attractive (Bloch, 1995, Karjalainen and Snelders, 2010).

Major corporations invest hundreds of millions of dollars in planning and conducting research on styling strategy, and the success or failure of many firms is determined by these decisions (Moulson and Sproles, 2000). Further to this, as technology becomes stagnant/standardized in a particular product, companies use aesthetics and stylistic innovation when competing for market share (Cappetta et al., 2006, Warell et al., 2006, Van Breemen and Sudijono, 1999).

As discussed in section 4.1, aesthetics of visual form of a product have the power to communicate and elicit some response from consumers. This section looks into strategies adopted by companies to use this phenomenon to gain competitive advantage. These are demarcation and distinction, Expression of function and properties and trends and fashions. These are now discussed in further detail.

4.3.1 Demarcation/ Distinction

Person et al. (2008) outline the marketing strategy of demarcation and distinction by communication through aesthetic features.

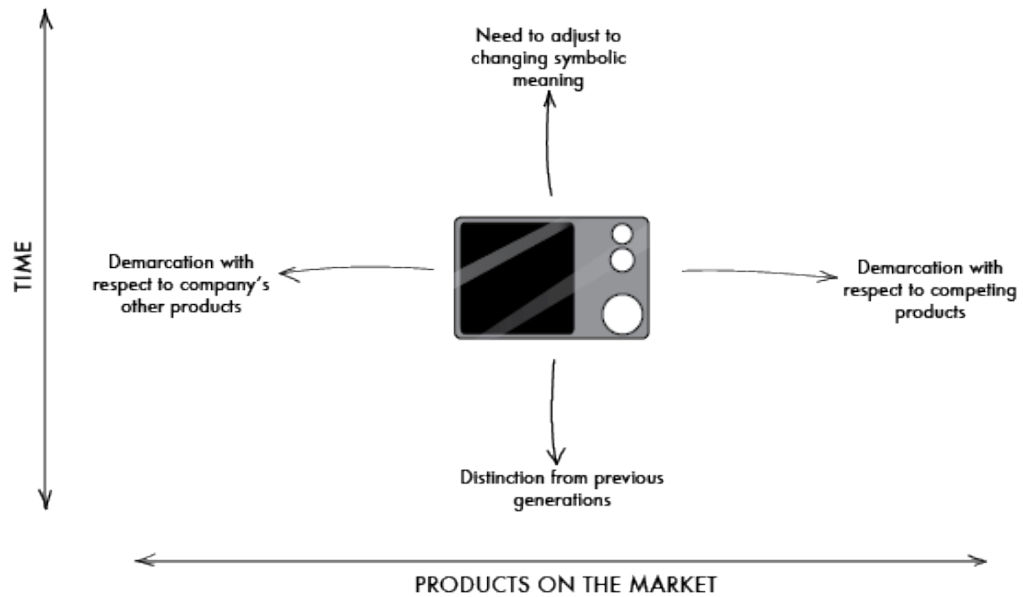


Figure 33 Use of aesthetics in product demarcation and distinction adapted from Person et. al. (2008)

Figure 33 shows three motivations for styling products. Distinction from previous models suggests that a new product should look different from its predecessors in order to highlight the 'newness' while also expressing an improvement on the previous versions.

Manufacturers also need to develop styling in response to changing symbolic meaning. This states that over a number of product generations their applications and target market can change. Changes in symbolic meaning are also driven by fashion cycles, this is explained further in section 4.3.3.

Moulson and Sproles (2000) research marketing strategies adopted by car manufacturers when considering aesthetics in relation to existing and previous products. A compromise between two extremes in styling is identified in creating a desirable looking product. At one extreme designers may not be 'far-reaching' enough with designs and create a product which is too conservative and considered uninteresting. The other extreme is that designers 'reach too far' with designs such that they are perceived as wholly unfamiliar and ugly.

Moulson and Sproles (2000) also distinguish two extremes of consumer, early and late adopters, proposing that consumers are distributed somewhere between these

extremes. Early adopters are characterized by those with a greater propensity to adopt new and innovative styles, while late adopters are those who do not.

Based on the compromise designers make in designing new product aesthetics and on the nature of consumers, they propose the following model (Figure 34) for successful styling strategy in the automotive industry.

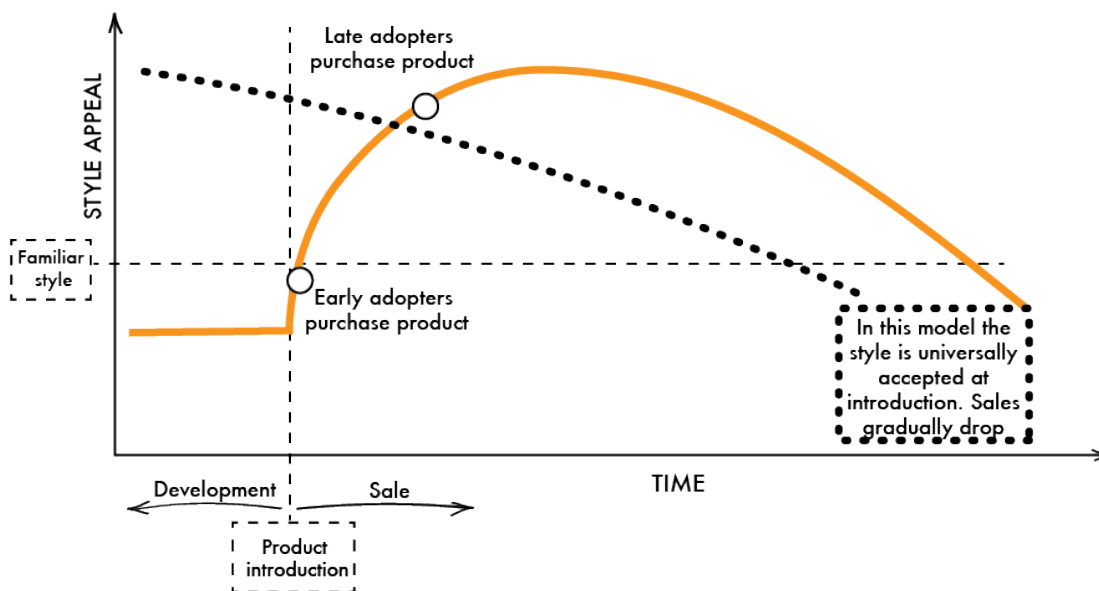


Figure 34 Model of successful styling strategy adapted from Moulson & Sproles (2000)

This indicates that new designs should not necessarily be universally liked at their introduction onto the market, they should simply be liked enough by early adopters to induce an increasing appeal of the design over time. This increase of appeal in late adopters is said to be driven by late adopters being exposed to advertising and viewing the vehicle in ‘real-life’ situations.

This model is underpinned by the concept that often consumers/ focus group members do not express an accurate opinion of a product. It is suggested that the environment in which studies and surveys are conducted show vehicles out of context, resulting a ‘tepid’ response to designs (Moulson and Sproles, 2000).

This model also suggests that all design/redesign processes are of similar approximate cost. Although this is potentially rational, it could be argued that less far reaching designs require less design work and less research due to their similarity with previous designs. Many industry case studies and interviews conducted while researching the

nature of the vehicle styling process indicate that no two projects are exactly the same, hence do not cost manufacturers exactly the same.

Despite these criticisms of the model proposed by Moulson and Sproles (2000), their research plainly illustrates the role of the designer in judging a difficult compromise between soft design constraints when evaluating potential aesthetic designs. Note this relates to the second key finding from interviews with practicing designers, in that demarcation and distinction is an example of a constraint that is particularly challenging to manage and communicate design rationale to other stakeholders.

4.3.2 Expression of Function and Properties

Norman (2002) discusses the concept of semantic constraints to design. This is the idea that certain forms communicate the mode of operation to the user. The two following examples are used, for example the traditional form of a motorcycle with handlebars and seat located as they are, instructs the user as to where they should sit on the bike, and how they should steer it. By way of a further example is a car's door handle. Certain forms clearly communicate to the user which movements of the handle open the door.

Mono (1997) elaborates on ideas of aesthetics expressing function, including the expression of properties. Here expression of properties means to use aesthetics to describe something about the product. Examples given are of heavy machinery looking 'stable' and 'robust' or an intercity train looking 'fast'. Both examples emphasize a particular property relating to the object's function.

Crilly et al. (2008a) concur with this, discussing the use of aesthetics to support comprehension of function and to foster recognition of product type. In other words, aesthetics can also help consumers to understand what they are looking at and how it works, thus identifying its relevance to their needs.

As well as designing products to look different and be distinguishable from competition, it is shown that products must also be designed to be similar such that their function and context is still easily identifiable. The need for identifiable function and expression of other qualities thus adds a further dimension to the compromise faced by designers in demarcation and distinction.

4.3.3 Trends and fashion

Cappetta et al. (2006) describe fashions or trends in relation to products as stylistic innovation. This is differentiated from technical innovations in products which can also facilitate changes in appearance. Cappetta et al. (2006) further define stylistic innovation as re-assignment of social meaning and/or aesthetic characteristics of a product. In other words, the creation of new or different intangible meanings of products. This reassignment of meaning is driven by the press and media emphasising (new) symbolic meanings that become attached to products.

McDonagh et al. (2002) describe material possessions as being symbolic expressions of who we are through expressions of personality, social standing and wealth. Hence the function of fashions and trends are based on the innate human desire for belonging and acceptance within an aspirational group (Pesendorfer, 1995). Further to this, humans use material possessions to express and symbolize their membership of certain aspirational groups within society. (Pesendorfer, 1995, Solomon, 1983, Sproles, 1981). The reason that fashions change over time is the inherent dynamic nature of aspiring to belong to a socially higher group.

Cappetta et al. (2006) propose a model to represent the changing nature of aesthetics in fashion cycles. In the same way that products go through stages of technological incremental change and innovation, so do fashions. It is stated that established companies within an industry thrive during stages of incremental stylistic change as they can consolidate a particular style and hence symbolic attributes, further differentiating their product in the market place. Conversely it is found that during periods of stylistic innovation new less established companies can thrive by producing 'far reaching' designs and beginning to establish themselves in the market. This aligns to the broad idea of styling strategy discussed in 4.3.1, detailing a compromise in which the designer must evaluate how far to develop a new product aesthetic.

4.3.4 Visual Branding and appearance

Although branding is considered as one of the strategic uses of appearance discussed in 4.3.1 - 4.3.3, its nature in encompassing aspects of all strategies means that it is considered in greater depth.

To begin discussion on brand it is first necessary to define what is meant by the term brand. The word brand originates from brand as a tool used to mark livestock such that it could be distinguished from other livestock. Hence the most basic definition of branding is some attribute incorporated into a product that distinguishes it from other products with a similar function (Keller 2008). Keller also expands on this basic definition of brand stating that in modern society, brand has become more than distinguishing attributes. The modern definition of brand is particularly amorphous including such definitions as manifestation of differentiation, a promise and any attribute associated with a product or service (Millman, 2011a). Reflecting this, the subject of brand and branding forms a considerable area of study with many facets. Visual branding merely makes up one of many components. It is not the aim nor is it within the scope of this research to discuss brand and the branding activity as a whole in any significant depth. This research focuses exclusively on visual branding, from here on defined as aspects of brand embodied in appearance.

In discussion of the meaning and nature of brand and visual branding it is also necessary to define the meaning of the term product. A product can be used to describe anything that can be offered for consumption in the market (Keller 2008). For example this could be tangible goods, businesses, services or even social or political causes. For the purposes of this thesis the term product is now used to describe tangible consumer goods, as it is these that form the focus of this research.

Brand and product appearance

Having introduced the concept of brand and how it is defined in this work, the relationship between products' appearance and branding is now considered. It is said that product is the primary influence on consumer perceptions of brand (Keller 2008; Karjalainen 2005 & 2003). This statement is crucial in that it introduces the concept that the nature of a product reflects on perceptions of its brand. Despite the general concept that brand is embodied by more than just products and their attributes, it is these product attributes, and their associations, which primarily influence perceptions of brand. It is noted that factors such as advertising also play a significant role in brand recognition and awareness (Takamura 2007) but are not considered in this research.

In consideration of the significance of different attributes of products, it has been shown that visual properties of products that most influence product perception (Bloch 1995; Page and Herr 2002; Kreuzbauer and Malter 2005). Thus as products reflect on brand perception, it is the visual properties of products which contribute considerably to this influence on brand recognition and perception.

This relationship between brand perception and visual properties is further reinforced when examining literature on the management of appearance and brand. Schmitt and Simonson (1997) highlight a variety of ways in which aesthetics may be used in marketing and branding strategies. These include the use of colour, size, shapes and typefaces to maintain a brand style. (Schmitt and Simonson) use the Gillette brand to illustrate this highlighting certain shapes and colours said to be representative of the brand.

The concept of visual material being significant in the representation of brand is further demonstrated by a project by DorothyDesign (2011) in which images created identify well recognized brands stripping logos down to celebrate the simplified shapes and colours that communicate so much in embodying brands. From response to these works it is clear that these visual references alone are enough to trigger recognition in consumers (DorothyDesign, 2011).



Figure 35 You took my name project by DorothyDesign demonstrates the use of colour and simple shapes in brand visual language

Further than logos demonstrated above, Coca-Cola maintains a strong brand image through the use of typeface and shapes in products. The iconic Coca-Cola bottle has been perpetuated throughout its product range over the years, whether used in the shape of containers or referenced in graphics where container shape is more uniform. Figure 36 shows the examples of the use of shape in product form along with colour and typeface in Coca-Cola packaging.



Figure 36 Range of Coca-Cola branded products exhibiting carefully managed visual cues

Visual impression significant to brand can also be extended beyond products and their packaging. Apple is a well-documented example of a company that uses strong aesthetics in its product design. It can be seen that this is perpetuated through to retail spaces that are also carefully designed to align with products' design. Figure 37 shows the current aesthetic themes adopted by Apple PC's of brushed aluminium casing, sharp edges and bold central logo. The use of aluminium panels in angular forms and similarly centrally placed logo is also perpetuated through the design of their retail spaces.



Figure 37 Apple's current aesthetic theme in products and retail spaces

All of the aforementioned examples demonstrate the careful management and application of what can be termed visual references to brand (Karjalainen, 2003a, Karjalainen, 2003b, Karjalainen and Snelders, 2010b).

Management of visual references to brand in product design and particularly vehicle design has been the focus of research for Warell (Warell, 2001, Warell, 2004, Warell et al., 2006) and Karjalainen (Karjalainen, 2003a, Karjalainen, 2003b, Karjalainen, 2007, Karjalainen and Snelders, 2010). Both studies research the identification of symbolic cues in appearance or visual references to brand and its management to maximize positive brand identification and perception. The details of these studies are discussed in greater detail in sections concerning consumer response (4.2.2).

4.3.5 Registered designs

Relating closely to strategic use of appearance and particularly visual branding is the subject of registered designs. *‘A registered design is a legal rights that allows a company or individual to protect the overall appearance of a product or part of a product’* (I.P.O., 2011b). In other words this is the legal recognition of the strategic use of appearance to create appeal and gain competitive advantage. This is particularly relevant in consideration of visual branding as demonstrated by legal action between brands (2007, 2010, McElhinny et al., 2011, Warman, 2011). In these cases companies have used registered design rights to protect aspects of their product’s appearance believed to be significant to their brand. Hence the litigation revolves around claims that competing companies are using particular aspects of appearance to gain competitive advantage to the detriment of the company holding the registered design.

While further demonstrating the strategic use of appearance, protection of registered designs also presents a further dimension to the contribution of this research. When considering the application of design rights and legal action relating to their infringement, there is a requirement to evaluate appearance. As with the styling design process (3.3.7) alleged infringing designs are currently evaluated subjectively relying on the experience and skilled argument of intellectual property lawyers (I.P.O., 2011a), acknowledged as being particularly imprecise (Proctor & Gamble vs. Reckitt Benckiser, (2007). Hence the proposed method for measuring and comparing product appearance would contribute by providing an objective/quantitative understanding of the similarity in appearance of disputed designs.

Summary of the strategic use of appearance to gain competitive advantage

This section explores the ways in which appearance is strategically used to gain competitive advantage. In doing so specific factors that are considered when evaluating appearance during the design process are raised. These are summarized as the use of appearance to: provide distinction, align with fashions and trends and express product type and function, finally encompassing all of these aspects is the consideration of branding with respect to appearance and its protection through registered designs.

Thus the range and number of factors show that consideration of appearance is is multifaceted in nature and hence complex to evaluate and reason upon. It is noted that the underlying in the consideration of these factors is the similarity or difference in appearance with respect to other products

4.4 Concluding remarks

The previous chapter highlights the essential role of evaluation and difficulties in evaluating appearance due to its subjective nature. Thus this chapter reviews the factors that influence product appearance. The chapter achieves this by addressing consumer response to appearance and strategies to link appearance with particular types of response. It also reviews the strategic use of appearance to generate appeal/gain competitive advantage.

A survey of the literature on consumer response discusses the mechanisms by which appearance can influence consumers and rationalizes/structures the different possible responses of consumers. Literature on design for consumer response explores the link or mapping of particular consumer responses with elements of appearance. While the approaches reviewed are shown to provide designers with insights on responses that can be elicited through appearance as well as strategies to link responses to appearance, they remain quite subjective. This is due to the focus on the consumer and consideration of aesthetic character. An exception is in consideration of brand, a more objective concept, and hence insights gained are less subjective.

Research into the strategic use of appearance focuses less on character outlining a number of factors to be considered to use appearance to gain commercial advantage. These factors are shown to be multifaceted and thus complex to evaluate and particularly to communicate to other stakeholders in the design process when reviewing appearance. It is also noted that despite the complex nature, they can all be considered in terms of similarity or difference from other products.

In consideration of the need for a more objective approach to review appearance during styling (presented in the previous chapter) two areas are identified as being particularly significant. These are consumer response with respect to brand and the review of appearance in terms of similarity with respect to strategic factors. Brand is significant as it is a less subjective topic to review in terms of appearance as well as being shown to be of particular importance strategically. Similarity is particularly significant as it is considered to be an aspect of appearance that can be rationalized and measured generically and thus objectively.

Thus the major contribution of this and the previous chapter, and thus the focus of this thesis, is in demonstrating the need for an approach (tool) to measure and compare product appearance and in highlighting the areas of branding and strategic similarity as areas of appearance in which measures are most applicable.

5 VISUAL DECOMPOSITION OF MASS MARKET PRODUCTS

This chapter describes the creation of an approach to decompose appearance into geometrical features in order that the relationship between geometry and visual branding may be explored. The approach created is termed ‘visual decomposition’ as the process created revolves around the concept of breaking down appearance into constituent features to investigate their influence on recognition of brand. Aspects of it are used throughout the remainder of thesis as a basis to investigate appearance.

The chapter begins by discussing the requirement for visual decomposition of appearance. The chapter then reviews the literature reporting strategies previously used to breakdown or decompose visual material discussing their various drawbacks and merits. Following this an approach for visual decomposition of mass-market products is proposed. This is done in two stages, the first is concerned with the definition of a rational categorization for features that constitute product appearance and the second discusses the representation of features following their categorization for further exploration.

5.1 A review of visual decomposition strategies

A number of major studies have been conducted exploring the decomposition and isolation of product images in order to gain a better understanding of the visual material which are now discussed highlighting the merits and drawbacks of different methodologies adopted.

5.1.1 Isolating geometry in drawings

Biederman (Biederman, 1987, Biederman and Ju, 1988) conducted studies decomposing line drawing representations of products to explore human understanding of images. In his initial study Biederman (1987) decomposed images of products in a

variety of ways and showed the decomposed images to participants measuring the length of time it took for them to correctly identify the product. Decompositions of images were based around the removal of parts of line elements that constituted the image. Using this approach it was possible to explore which lines or segments of lines were most important for human recognition and understanding. It was found that the vertices in line representations of products were most influential for human understanding. This was demonstrated in the way that respondents could not identify products when vertices were degraded, yet could identify products where mid-segments were removed. In a second study (Biederman and Ju, 1988), the differences between understanding of line representations of products and representations which include surface details were explored. Participants were shown pictures of products isolating surface and edge parts of the images. This study verified the findings of the initial study as it was found that edge properties have far greater impact on human understanding of objects

The relevance of these studies to this thesis is primarily in the experimental method adopted. They demonstrate that a strategy of decomposing images to varying degrees of detail is a suitable approach for exploring the effects of constituent features of a product on human perceptions.

The work of Prats et al. (2006) in exploring designers' sketches demonstrates a similarly suitable approach to visual decomposition. The aim of their research was to enhance designers' creativity when sketching by developing a tool to generate shape explorations. In order to develop such a tool, the strokes and transformations made by designers while sketching were decomposed and isolated. This approach to visual decomposition provided further insight into the influence of particular elements of sketches on the generation of product form, for use in the development of generative sketching tools.

Work by Tovey et al. (2003), considered sketching in automotive design and the technique of 'de-layering' to visually decompose drawings. The de-layering process consists of decomposing sketches made by students and professionals into 'form lines', 'components', 'form shading' and 'non-form shading'. The study showed the form lines to be most expressive and carry the intentions of the designer. Where Prats and Biederman present methods to decompose line representations of products, the

work of Tovey differs in that it presents a method to visually decompose images including richer detail and more realistic details such as those from shading surfaces.

Cleveland (2010) investigated the role of visual style in graphic design styles. A methodology was proposed to aid designers by reproducing graphic layouts within the same style. In creating this methodology, Cleveland decomposed layouts classed as belonging to a particular style by the geometric relationships between constituent features. Relationships include proximity between features and their placement within a page. Trends identified in geometric relationships form the rules by which layouts may be automatically generated. While this research is not directly applicable to general products due to the two dimensional nature of graphic design, it does illustrate the way in which geometric rules can be used to characterise visual styles.

5.1.2 Identifying aesthetic features

The FIORES projects aimed to improve the working procedures and computer aided tools for modelling aesthetic shapes (Cheutet et al., 2008) by studying ‘aesthetic key lines’. These were defined as lines on a vehicle surface that were thought to be aesthetically important. The aim was to help preserve the original design intent through the complete vehicle design process. Previous work defined curve geometries in the terminology used by stylists (Podehl, 2002). The decomposition strategy used was based on isolating ‘aesthetic key lines’ from front, side and rear views of vehicles. The isolated lines were then reviewed with respect to the terminology and curve geometry. Data was used to create an ontology of curves linking quantitative properties from digital models with aesthetic properties based on stylists’ terminology. The key relevance to this thesis is the identification, extraction and isolation of aesthetic features of vehicles.

In a similar manner, the works of Pugliese and Cagan (2002) and McCormack et al. (2004) investigated the use of shape grammars to generate designs for motorcycles and cars that contain brand specific aesthetic features. Shape grammar is a term used to describe a set of geometric rules that can be applied to create geometry in a particular style. In order to create a shape grammar the aesthetic features of existing products had first to be explored. This was done by first simplifying images into two dimensional line representations. Shape grammars were then used to generate a range of alternative

concepts experimenting with aesthetic features and recognition of brand. As well as adopting an approach of visual decomposition to explore aesthetic features, this research also shows that simple two dimensional line representations of vehicles can still contain enough visual information to provide some of the aesthetic characteristics when conducting visual decompositions.

Warell (2001) addressed the concept of visual decomposition of products. He explored the nature and workings of visual aesthetics to support development of product form. Within this study Warell visually decomposed images of products, defining constituent aesthetic features as belonging to different categories termed 'form entities'. These are defined by their 'visuo-spatial' configurations (how they appear with respect to other aesthetic features). Having categorized product features as belonging to different form entities, the perceptual effects of aesthetic features (syntactic function) were investigated. Doing this was said to enhance understanding of form, structure, content and composition in the design of products.

Warell's work demonstrates yet another approach for visually decomposing images to better understand aesthetic features in product designs. Warell verified this decomposition technique in further studies (Warell, 2004, Warell et al., 2006), where decomposition of products by form entities was used to explore consumer perceptions of alternative product designs.

Karjalainen (2007) also explored the aesthetic properties of vehicles and their branding through visual decomposition. A range of vehicles of a particular brand was visually decomposed in order to identify explicit visual references. These were defined as references embedded within design features, implemented by designers with the intention of being easily recognized and perceived as belonging to a particular brand. The explicit visual references identified were then used as a basis for designing different products but still identifiably of the same brand. Results showed that such analysis of the product range and isolation of features could be used as a basis to design products exhibiting distinct brand features.

Liem et al. (2009) presented a further study into recognition of aesthetic features of vehicle form. This study aimed to explore how recognition is formed by visual elements in vehicle form. In order to achieve this goal Liem et al. decomposed different views of a vehicle into individual components. Next a group of designers was

asked to highlight the components they thought to be most expressive and thus able to trigger recognition. Although this study does not decompose images to the point of isolating components for further investigation, it provides a valuable example of a strategy to identify types of visual features that constitute vehicle form which could be decomposed.

While all of these strategies are relevant to the creation of the visual decomposition approach in that they all address product appearance, no single approach is adopted exclusively for this thesis. Rather, aspects of a number of the previous approaches most suited to the proposed visual decomposition approach are drawn upon. Line and curve segments are used to outline features as in Biederman (1987) which are then assigned to categories as in Warell (2001). Categories of features may then be reviewed by consumer groups as in Liem et al. (2009).

5.2 Proposed visual decomposition strategy

The decomposition strategy used in the work reported in this thesis is defined in three sections. The first section defines the base visual material onto which the visual decomposition is applied. The second section discusses the tracing of features and the derivation of feature outlines from base visual material. Finally the third section addresses the definition of categories into which features may be assigned. The proposed decomposition strategy is summarized in Figure 38 and further elaborated on the following sections.

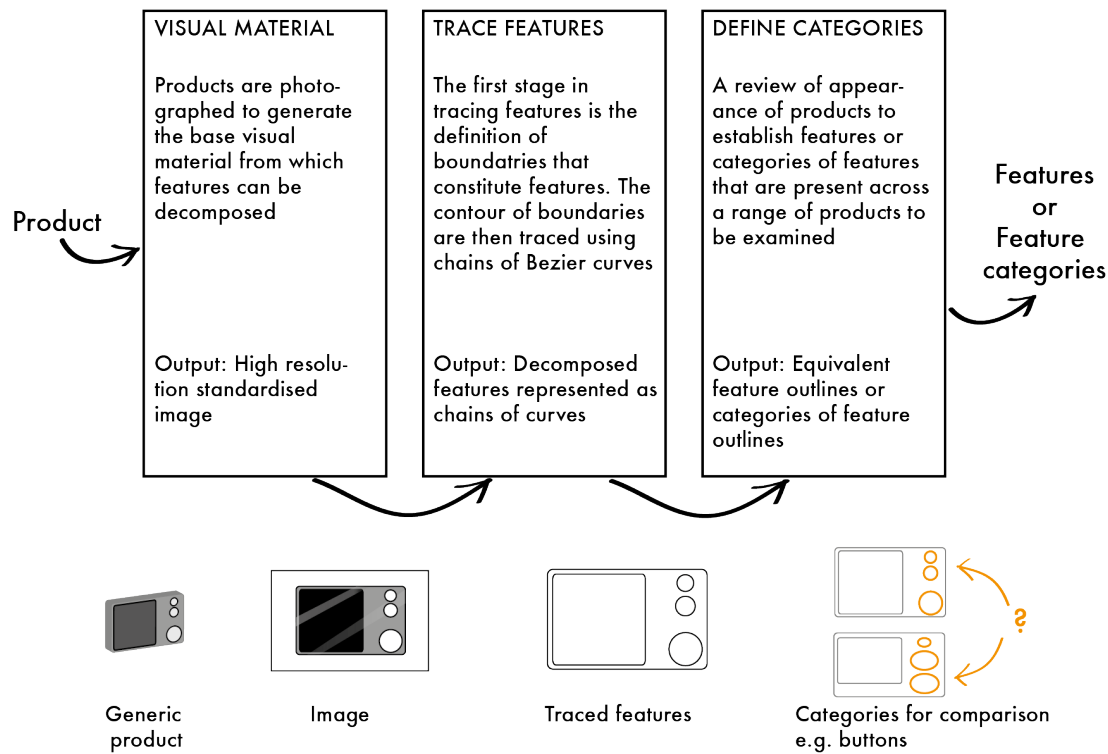


Figure 38 Summary of steps addressed to achieve visual decomposition

5.2.1 Visual material for decomposition

For the purpose of this study photographs are to be used as the base material from which the approach is to be applied. Photographs have been selected over the alternative of actual products and 3D surface models for a number of reasons. Firstly the proposed technique is digitally based/orientated thus with respect to using actual products, there is a requirement to digitize product geometry. It is not within the scope of this thesis to obtain a number of vehicles and use scanning equipment to obtain geometry.

One alternative would be to use 3D surface models of vehicles, thus already in a digital form. However, due to reasons of confidentiality it is not possible to obtain access to this information from competing vehicle manufacturers. Furthermore it is not within the scope of the study to recreate accurate digital models for vehicles assessed.

In comparison to actual products and digital models, photographs are readily accessible for vehicles but also for other products and for older products where digital models may not exist. Hence this approach uses vehicle photographs in front, side and rear elevations as base material for applying the visual decomposition technique.

The first limitation induced by the use of photographs is that accuracy in tracing features is dependent on image resolution. Image detail also has an effect on the ability to define what constitutes the boundary of features. This becomes particularly difficult when attempting to apply consistent judgement across different types of product. There is also an inherent limitation in that resulting geometry is 2 dimensional and hence an abstraction from reality. Use of 2 dimensional representations has however been shown to sufficiently communicate product type (Biederman, 1987, Biederman and Ju, 1988) and visual branding (McCormack et al., 2004, Pugliese and Cagan, 2002, Ranscombe et al., 2011).

5.2.2 Tracing features

Features are traced for a number reasons. Firstly, due to the use of images as a base material, representation is also 2 dimensional. Secondly the purpose for creating this approach is to begin to answer RQ1 investigating the relationship between geometry and visual branding. As geometry is the subject of study the representation of features should embody feature geometry. Furthermore this must be done in the absence of other factors that may also influence/constitute visual representations of brand such as colour, material or texture. Finally this mode of representation also removes the influence of photographic factors such as subject lighting or setting.

As shown in Figure 38 the first stage in being able to trace features is to define what constitutes their boundary or outer edge. The rationale for defining feature boundaries depends greatly on the nature of the products investigated. For the purpose of applying the method to vehicle features, boundaries are defined by change in material, the physical boundary between two parts and in the case of some surfacing features, the apex in the surface that forms the feature line.

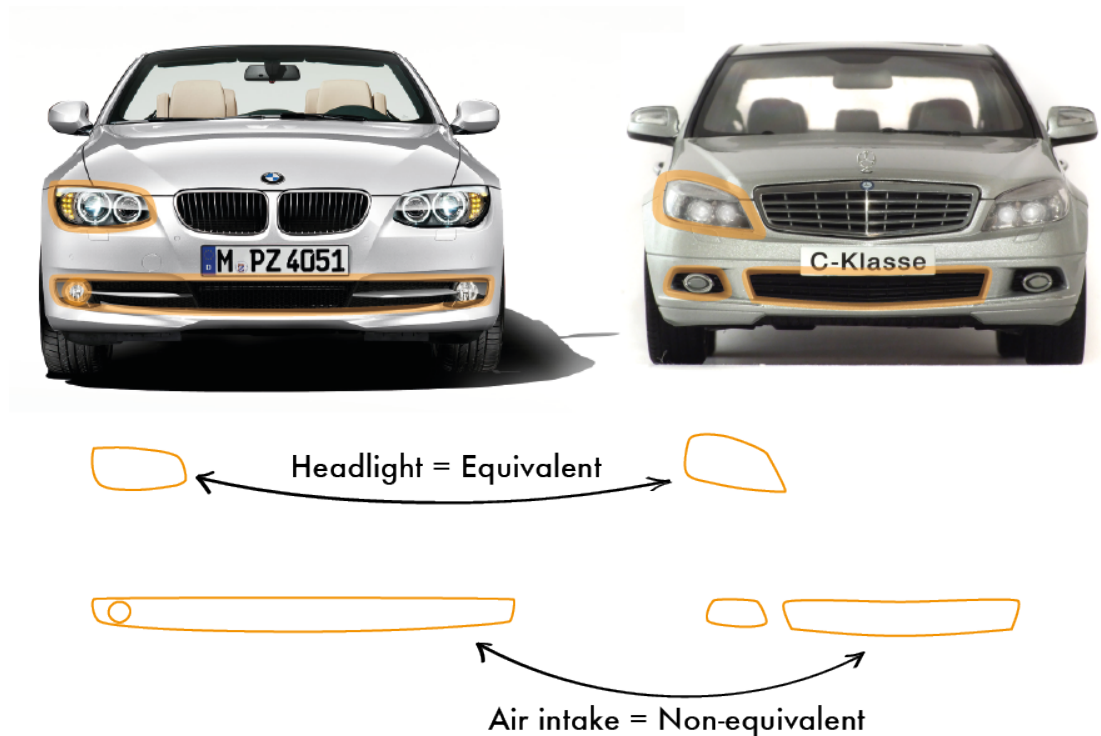
It is acknowledged that tracings of feature outlines do not communicate in the same way as the complete product in real life. However in light of the studies reviewed in section 5.1, (Biederman, 1987, Biederman and Ju, 1988, McCormack et al., 2004, Pugliese and Cagan, 2002) 2 dimensional line representations have been shown to contain enough detail to evoke recognition. Furthermore it is asserted that there are many instances in product advertising where brand can clearly be communicated without complete and realistic product images.

The tracing activity consists of using Adobe creative suite graphics software (Adobe Photoshop and Adobe Illustrator) to scale images to the same fraction of relative size. The images are then traced using Bézier curves. The curves are connected into a chain that forms the outline of features. Using chains of curves means that outlines can be traced in high detail with relative ease. Chains of Bézier curves are used as they can be more easily manipulated to pass through specific points rather than B-spline curves or NURBS (non uniform rational B-splines). Additionally Bézier curves are easier to edit as other parts of the curve/chain of curves are unaffected, thus making it easier to adjust curves to fit outlines. Curves are plotted as a vector entity on a 'layer' superimposed over the photograph, a raster graphic. The advantages of this are that the feature shapes are not resolution/pixel dependent. The accuracy associated with this approach is readdressed when applying the technique for quantitative experimentation (chapter 7).

5.2.3 Defining categories for decomposition

Defining categories of features is of primary importance for making comparisons between products so that fair judgments or conclusions may be drawn from comparisons of appearance. If products to be compared are highly similar and have features that can be said to be equivalent, the features can be compared directly without the need to create comparisons. This type of comparison is seen in chapters 7 and 9.

However it is contended that more often than not products do not have entirely equivalent features. In these cases there is a need to establish criteria to categorise non-equivalent features in order to make fair and accurate comparisons of appearance. Criteria may be based on the function of particular features, or by their form or role within the overall visual impression. Investigation of vehicle appearance is one such instance in which categories of features are required to make fair comparisons. Figure 39 illustrates the difference between equivalent and non-equivalent features using vehicles as an example. The definition of categories is discussed in the following section where the approach is applied to vehicles. It is noted that there is some value in making comparisons between non-equivalent despite the 'unfair' comparison. This is discussed further in section 10.3.



Headlights can be said to be 'Equivalent' while the air intake and foglight features are 'Non-equivalent'

Figure 39 Illustrating features which are said to be 'equivalent' and 'non-equivalent' using vehicles as an example

5.3 Applying the visual decomposition strategy for vehicles

The visual decomposition approach is now applied to vehicles. The definition of feature categories is first addressed and the traced features are next demonstrated in the defined categories.

5.3.1 Defining feature categories for decomposition of vehicles

It is viewed that one common theme among all vehicles is, to some extent, the process by which they are designed. Hence the process of designing vehicles forms the starting point for the derivation of categories used in the visual decomposition. The categories used here draw on studies discussed in section 3.3, as well as understanding gathered from practising designers, on the characteristic processes used to create the aesthetic features in designs.

Interviews (Appendix 1) reveal that, in order to generate research findings that are relevant and valuable for use in the styling design process, the steps taken by designers need to be considered in the creation of a decomposition strategy. Hence the strategy produced here is based on the sketching activity and steps taken by designers during ideation and realization stages to create overall vehicle form. From interviews the following types of aesthetic features are defined.

Outline: This is the boundary created between the vehicle and space surrounding it. It could also be termed the silhouette. During design the outline defines the vehicle's general dimensions or 'volumes'.

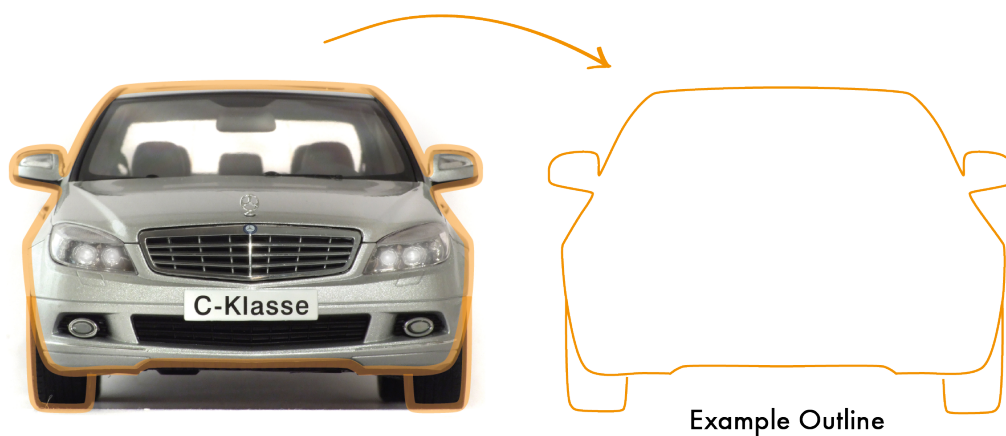


Figure 40 Example of an 'Outline' feature

Daylight Opening (DLO): This is defined by the front and rear windshields and side windows. The DLO is also referred to as the greenhouse. In terms of constructing the design of a vehicle and its overall appearance, adding the DLO defines the posture or stance.



Figure 41 Example of a 'DLO' feature

Muscles: These are treatments given to surfaces or panelling. These are often in the form of creases or curves created by raising or lowering sections of the surface. Such surface treatments are also referred to as character lines or light lines.



Figure 42 Example of 'Muscles' features

Graphics: These are described as markings on the vehicle. These included details such as headlamps, radiator grille and number plate. The addition of graphics to a design is usually the final step in creating a proposal.

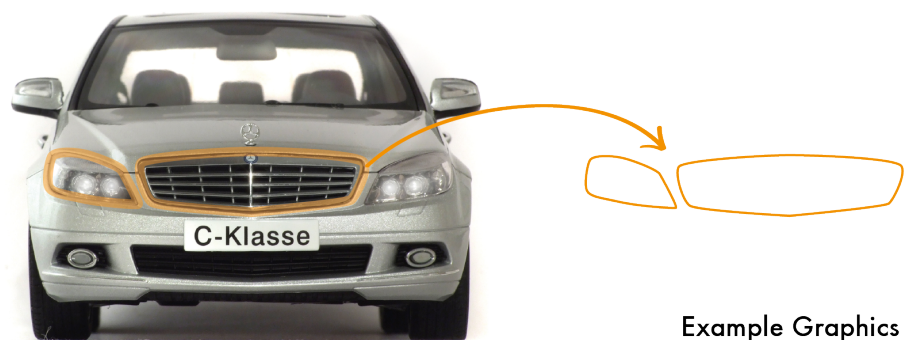


Figure 43 Example of 'Graphics' features

Explicit detail: This is a subcategory of graphics. It is made up of graphic features which explicitly indicate vehicle brand, such as badges and logos.



Figure 44 Example of explicit detail

Similar definitions are also seen in literature. Cheutet et al. (2008) and Tovey et al. (2003) make reference to muscles as surfacing that determines character lines and their importance to overall appearance. Warell (2001) defines overall outline or silhouette, connecting features manifested in the surface treatment (muscles) and discrete or discerning features (graphics), further reinforcing the suitability of the visual decomposition strategy. Outline, DLO, muscles and graphics form the feature categories used in the decomposition strategy created in this chapter. An additional category referred to as explicit detail was created for experimental reasons. Some vehicle manufacturer logos are known to be particularly memorable. Such features were thought to influence consumer recognition to such an extent that the influence of other graphics features would be misrepresented. Thus the logos and badges are separated into a further feature category.

5.3.2 Traced features

Following the method to trace features set out in 5.2.2, the features of vehicle appearance are traced from front side and rear elevation images. An example of the resulting tracings is shown in Figure 45. In addition to providing examples of the traced features, Figure 45 also shows the details of features included in different feature categories.

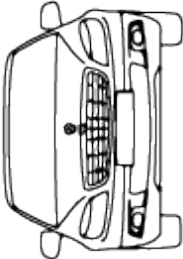


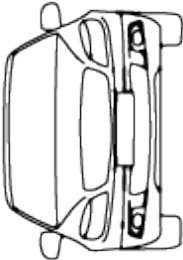





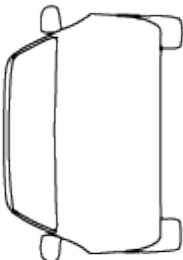


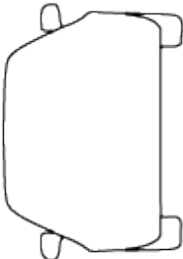
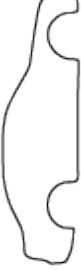

FRONT	SIDE	REAR	FEATURE CATEGORIES
			Outline DLO Muscles Graphics Explicit detail
			Outline DLO Muscles Graphics
			Outline DLO Muscles
			Outline DLO
			Outline

Figure 45 Decomposition strategy applied to front side and rear views of a vehicle

5.4 Concluding remarks

Directly addressing RQ1 and objective I, this chapter reports the creation of an approach to decompose appearance into constituent feature geometry such that it may subsequently be investigated.

Thus the major contribution of this chapter is in three parts that make up the approach; the definition of visual material that form the basis of the decomposition approach; the approach taken to trace features such that their geometry may be investigated; finally the approach to categorise features in order to make fair comparisons between features. These three activities within the overall visual decomposition technique are used throughout experimentation reported in this thesis.

The following chapter reports the application of the visual decomposition technique to a range of vehicles. Thus having created the approach in this chapter, the following chapter presents the use of said approach to address RQ1 and achieve objective II.

6 TESTING THE VISUAL DECOMPOSITION APPROACH

This chapter describes the testing of the visual decomposition approach set out in the previous chapter (5) by means of a consumer survey. The aim of the study is to investigate the suitability of the approach to isolate features and explore their influence in product appearance and visual branding.

The chapter begins by discussing the method adopted to test the visual decomposition approach. This includes the details of the features included in images shown to respondents and the questions asked in relation to images.

From the results the major conclusions and hence contribution to the thesis is twofold, addressing both objectives I and II. Thus the first contribution is in gaining some insights with regard to the influence of different types of features on the recognition of brand in vehicle design. The second and more important contribution is in the testing and validation of the visual decomposition approach that is to be used repeatedly throughout further experimentation in the thesis.

6.1 Testing approach

A web-based survey approach was employed in order to obtain a large participant population (400 plus). It was also easier to distribute and collect data compared with paper surveys. In terms of responses that participants give to questions, a web-based survey is far more rigid compared with paper survey or focus groups. Web-based surveys offer little opportunity to provide extra information or further thoughts on responses. For the purposes of this experiment the advantage in the ability to reach a greater sample size outweighs the possibility to capture participant reaction.

6.1.1 Selected vehicles

Five vehicles were visually decomposed for use in the survey, BMW 3 series, Audi A4, Mercedes-Benz C-Class, Ford Mondeo, and Honda Accord saloon models all from

the same year (2010). These vehicles were chosen because they were found to be in direct competition in terms of size, segment and price (Which?Car, 2010). Furthermore all of the vehicle brands were found to be in the top 100 global brands chart of 2009 (Interbrand, 2009).

6.1.2 Images

The images shown to participants consist of traced features as shown in section 5.3.2. The traced features were then layered together to create the different combinations of features/feature categories (section 6.1.3) to explore their influence on consumers. Combinations of features are then exported into images used in the web survey. Images were made to the following specifications. Images size of 520 x 367 pixels, approx. 140mm x 80mm when displayed at 1024 x 768 screen resolution. Isolated features were represented in 2pt thickness lines on a black background in order to maximise detail/clarity. Figure 46 shows one of the images used in the survey shown as it was presented to participants. The details of the combinations of features/feature categories included in different images are set out in Figure 47.

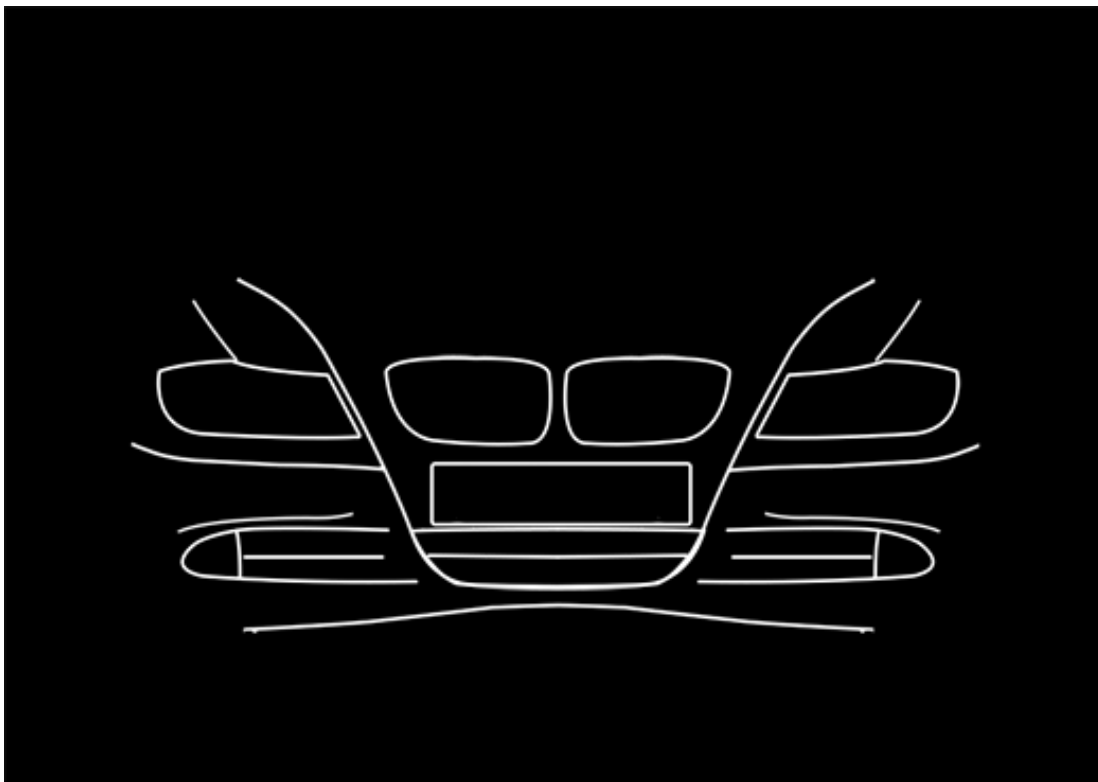


Figure 46 Example of decomposed images shown to participants in survey

6.1.3 Survey structure

The structure of the survey was based on displaying decomposed images of front, side and then rear views of vehicles. These formed three sections of the survey. Using five vehicles meant that there were 240 images of possible combinations of features (sixteen possible combinations of features per vehicle, using five vehicles, in three different views). Including all of the images would result in an exceptionally lengthy and repetitive survey that few participants would take the time to complete. Some combinations of feature categories, especially those containing explicit identifiers, were thought to reveal answers to subsequent questions. Other decomposition combinations were deemed to be so obscure that any correct identification would likely be down to chance. As a result, a sequence of 38 decompositions was selected. This showed most of the feature category combinations using a variety of vehicles yet avoiding explicit vehicle identification too early in the survey. The sequence of decomposition images shown to participants is illustrated in Figure 47.

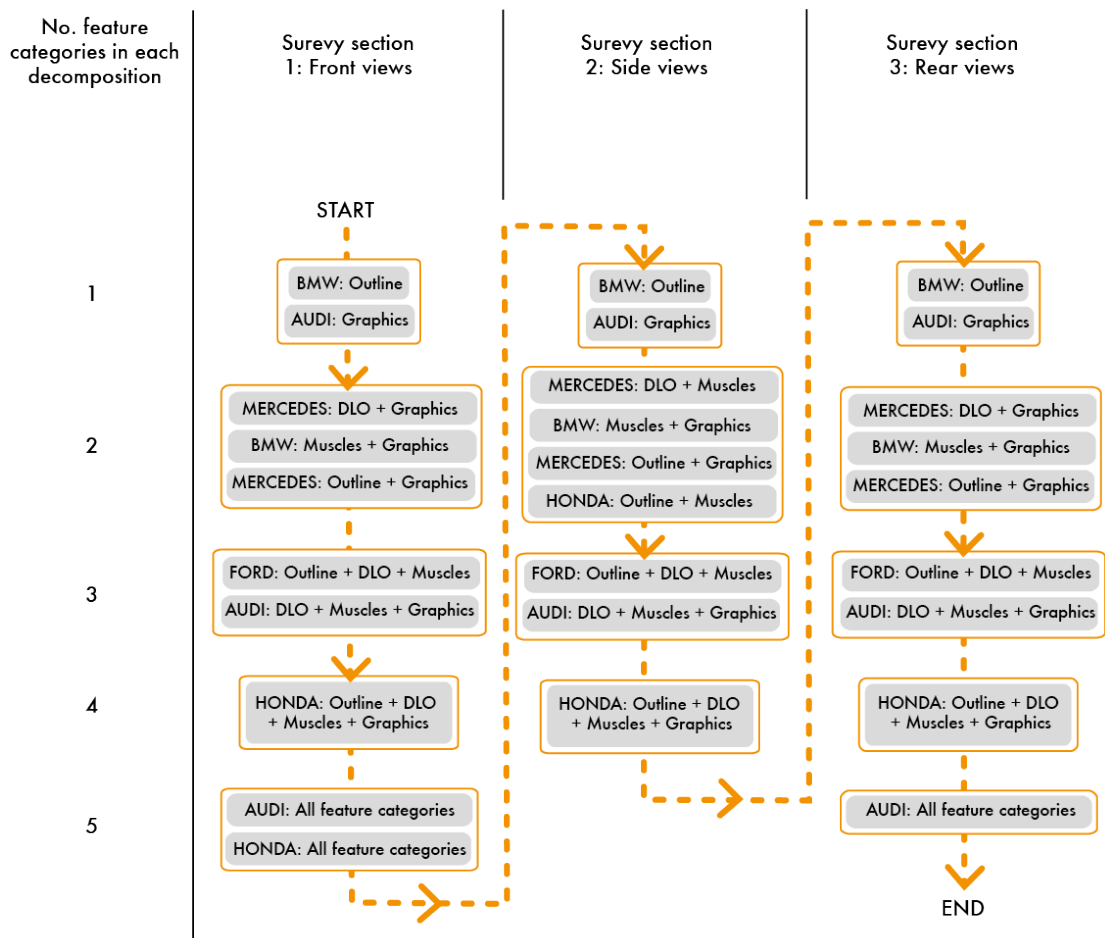


Figure 47 Sequence and details of decomposed images shown to participants

Participants started the survey with the front view containing a single feature category (BMW with only its outline included). Subsequent images showed front views with increasing numbers of features. After front views containing all features were shown the sequence was repeated for side and rear views. A number of points should be highlighted when viewing the sequence of images shown to participants. Firstly it can be seen that the same combinations of features on the same vehicles were used in all three sections/views. This was done for the purpose of consistency and comparability of results between the different views. However, it was also be seen that there were instances where the images deviate from this sequence. When visually decomposing the side view of vehicles, there were found to be no ‘explicit identifiers’. Hence, there could be no decompositions that included all five feature categories. Consequently a further decomposition including two feature categories was included (Honda: Outline + Muscles).

6.1.4 Questions

The primary question posed to respondents tested their ability to recognize vehicle brand, thus exploring the influence of features on brand recognition. Further insight into what participants recognised from different combinations of features was obtained by secondary questions concerning physical and subjective attributes that characterise the product appearance. These were the segment in which the vehicle is sold/retailed and the emotional character given in manufacturers promotional material. Thus a total of three questions (one primary question on brand and two secondary questions) were posed to participants in a multiple choice format for each decomposition. Table 4 shows the questions and the possible choices given to participants to select an answer from.

QUESTION POSED	Primary question: BRAND	Secondary questions: SEGMENT	CHARACTER
	'Which brand manufactures this car?'	'In which segment does this vehicle belong?'	'Which emotions best describe this vehicle's character?'
POSSIBLE ANSWERS	Not sure	Not sure	Not sure
	Audi	City car	Aggressive
	BMW	Small car	Dynamic
	Citroen	Medium/Family car	Elegant
	Fiat	Large/Estate car	Friendly
	Ford	Executive car	Modern
	Honda	Luxury car	Powerful
	Mercedes Benz	SUV/4X4/Off road vehicle	Sporty
	Nissan	MPV/People carrier	Stable
	Renault	Sports car	

Table 4 Questions posed to participants with respect to decomposition images and multiple choice answers

The rationale for presenting participants with ten possible answers (nine for the final question) was to include all characteristics that describe the five vehicles used in the survey, while adding additional options to reduce the probability of correct identifications from guesswork. In addition to questions relating to each of the images, a series of profiling questions was posed prior to the start of the survey. These questions concerned information about participants such as age, gender, a self-assessment of their ability to recognize vehicle brand and exposure to vehicles. Thus, participants were asked to record whether or not they held a drivers licence and for how long, how many hours they spent driving per week and their interest in brand and styling of vehicles. Participants were also asked to rate their confidence in their ability to identify the brand of a range of vehicles.

6.2 Results & discussion

The survey was made available online for five days from 24th February 2010. A total of 420 responses were recorded. Respondents were aged between 17 and 63 years old. 78% of responses were recorded by male participants and 22% by female.

With respect to the exposure of participants to vehicles, 89% of participants held a drivers licence and had had it for an average of 8 years. The average number of hours spent driving per week was 5.7 hours with a maximum of 65 hours.

The profiling questions revealed that 49% of participants held a car's styling as being 'very important' when considering purchasing a car while 43% responded 'mildly important' and 8% responded 'not important'. It was also found that 36% of participants held vehicle brand as being 'very important' when considering purchasing a car, while 50% responded 'mildly important' and 14% responded 'not important'. Finally it was found that from the vehicles included in the survey participants were most confident in their ability to identify BMW, with Mercedes second, Audi third, Ford fourth and Honda last.

Key results are shown in Figures Figure 48 -Figure 53 and discussed in sections 6.2.1 - 6.2.6 from which observations are made.

6.2.1 Influence on responses of increasing number of feature categories in decompositions

From the results it can be seen that displaying different combinations of feature categories elicits varying recognition of brand. Over the course of the survey the number of feature categories that make up an image increases. Hence as participants progress through the survey they are given increasing levels of information. However and somewhat surprisingly, the number of correct identifications of brand and vehicle characteristics did not increase proportionally with the increasing level of information (number of feature categories included) in each image. This is demonstrated in Figure 48 where it can be seen that the percentage of correct responses (represented by the dots) does not increase with the number of feature categories included in images (represented by the bars).

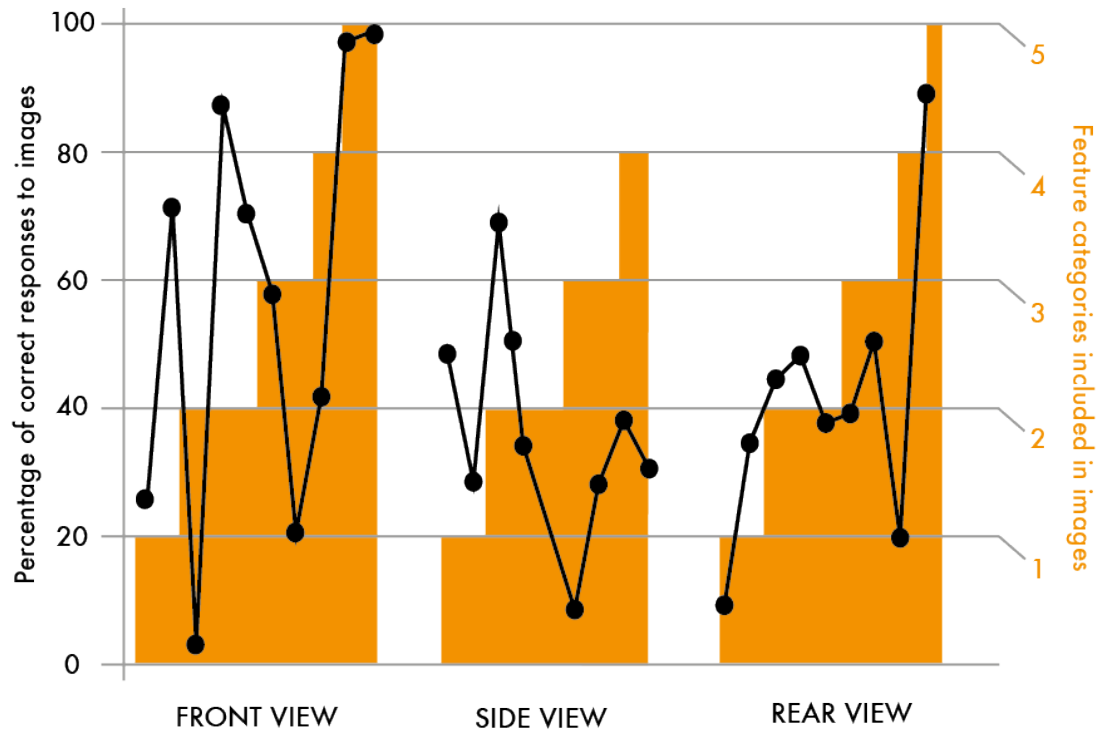


Figure 48 Demonstrating the lack of any correlation or trend between percentage of correct identifications of brand and the increasing number of feature categories included in images.

Conducting a Chi-test on survey data confirms this observation. The value for X^2 is close to zero in front, side and rear views showing that the percentage of respondents correctly identifying brand is independent to the number of feature categories included in decompositions.

The brand of decompositions containing all feature categories is correctly identified by a large percentage of participants (Figure 48). This is explained by the presence of ‘explicit detail’ such as logos in decompositions. In all views it can be seen that decompositions containing only one or two feature categories also repeatedly receive a greater percentage of correct responses than decompositions containing three or four feature categories. This pattern suggests that different feature categories have greater influence on participants’ perception of brand than others.

6.2.2 Significance of views

It is also noticeable that there are more correct identifications of vehicle brand and characteristics in images showing front views of vehicles. Average correct responses are annotated on data shown in Figure 49. The average percentage of correct responses to front views is 58%, while the average percentage of correct responses to both side

and rear views is 41%. These findings are in agreement with literature which states that the front view of vehicles is the most important single element for incorporating brand references (Chen et al. 2007; Karjalainen, 2004). Thus, this experimentation confirms the idea that aesthetic features in the front view have the greatest influence on consumer perception of brand.

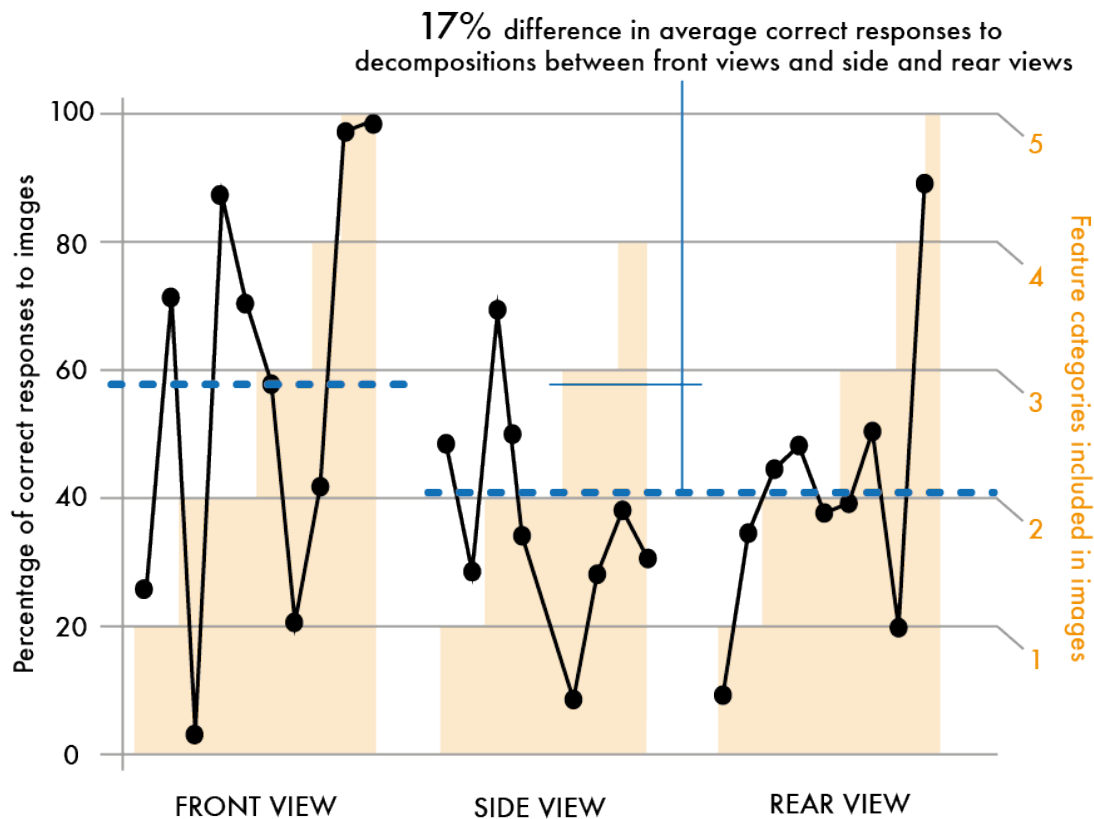


Figure 49 Illustrating that more respondents identify brand correctly when shown front views of vehicles

6.2.3 Responses to different questions

Throughout the survey, participants achieve less correct responses to questions on segment and character than to questions on brand. This is demonstrated by the average percentage of correct response to questions relating brand was 50.6%, while average percentages of correct responses to questions on segment and character were 33.0% and 32.5% respectively.

It is asserted that the reason for such a low average percentage of correct responses to questions on vehicle character seems to be due to the abstract nature of questions posed. It is thought that verbalizing vehicle's emotional character was found by

participants to be difficult, which is consistent with findings in McDonagh et al. (2002) on the use of images rather than text to express respondents emotions.

The majority of responses to vehicle segment were also incorrect. This was especially surprising for side views as it was thought that the vehicle outline and DLO would clearly indicate segment. It is thought that the explanation for these results is that terminology used to define segment, although technically correct (based on EuroNCAP classification (1999)) was found to be somewhat ambiguous. Further experimentation asking participants to identify segment pictorially could be undertaken to remove this ambiguity.

An exception to this is the case in which the side-view of the Mercedes (including DLO and muscles feature categories) is correctly identified by substantially more participants than other combinations of feature categories. The existence of this exception suggests that there is some element of this combination of aesthetic features that make it more recognizable and thus worth investigating further.

6.2.4 Influence of different feature categories

As previously stated, some feature categories have greater influence on ability to identify vehicle brand than others. On closer inspection of decompositions returning greater percentage correct responses, it can be seen that many of the decompositions contain the 'graphics' feature category (Figure 50). This suggests that the graphics feature category in the front view is more potent in communicating vehicle brand.

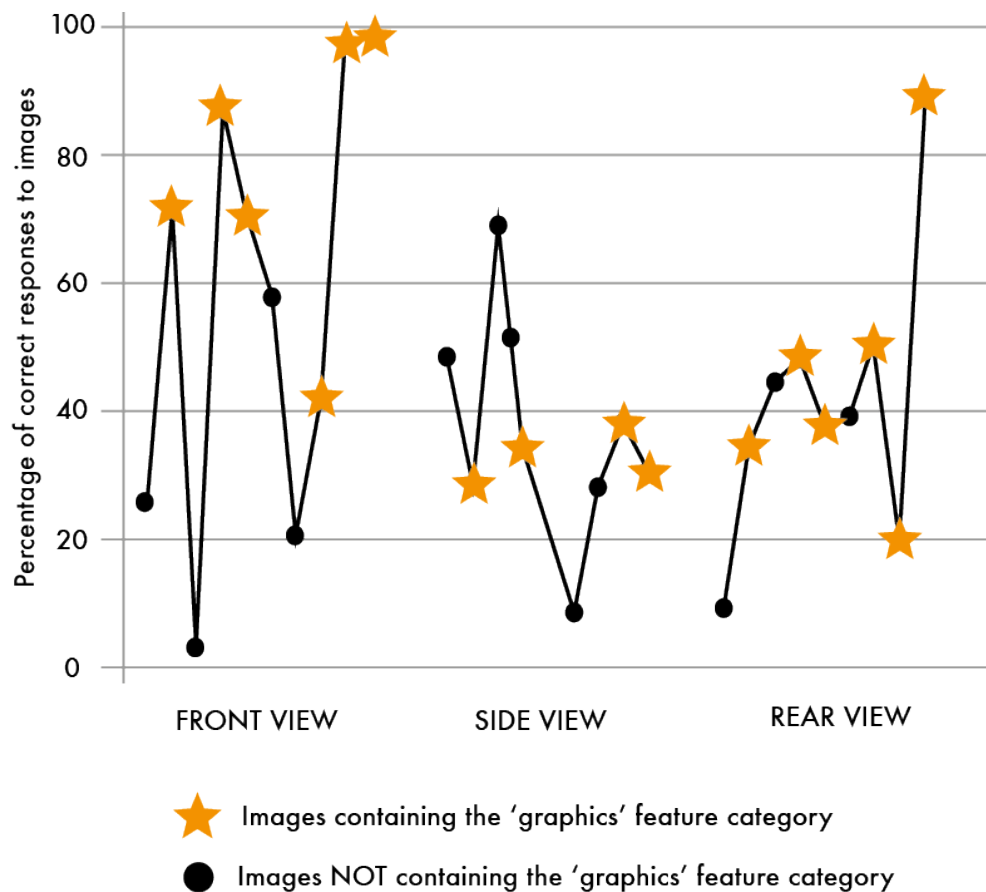


Figure 50 Illustrating images containing 'Graphics' feature category in the front view receive more correct responses

6.2.5 Influence of brand name

When analysing responses to different feature categories within specific vehicles, (e.g. the BMW in isolation), no common pattern can be seen (Figure 51). In other words, when the number of correct responses at different levels is looked at for specific vehicles, each vehicle exhibits a different trend. This is because none of the vehicles share common feature category combinations, as these were limited by constraints on the time and length of survey. It would hence be worthwhile extending this survey as part of further work to investigate potential patterns in visual breakdown of specific vehicles.

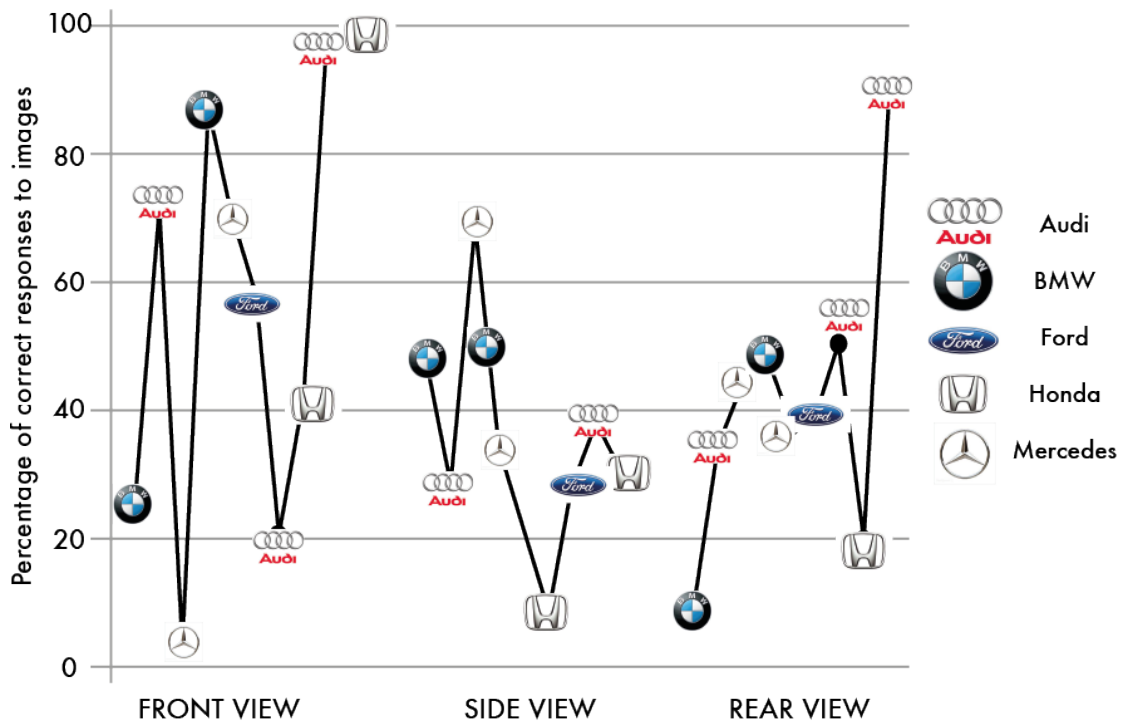


Figure 51 Illustrating that the range of correct responses with respect to vehicle brand

Results from the profiling questions prior to the start of the survey show that participants were the least confident in their ability to identify ‘Honda’ and ‘Ford’ brands. This is reflected when comparing correct responses with respect to the five vehicle brands used. It can be seen that there are less correct identifications of these brands and their characteristics.

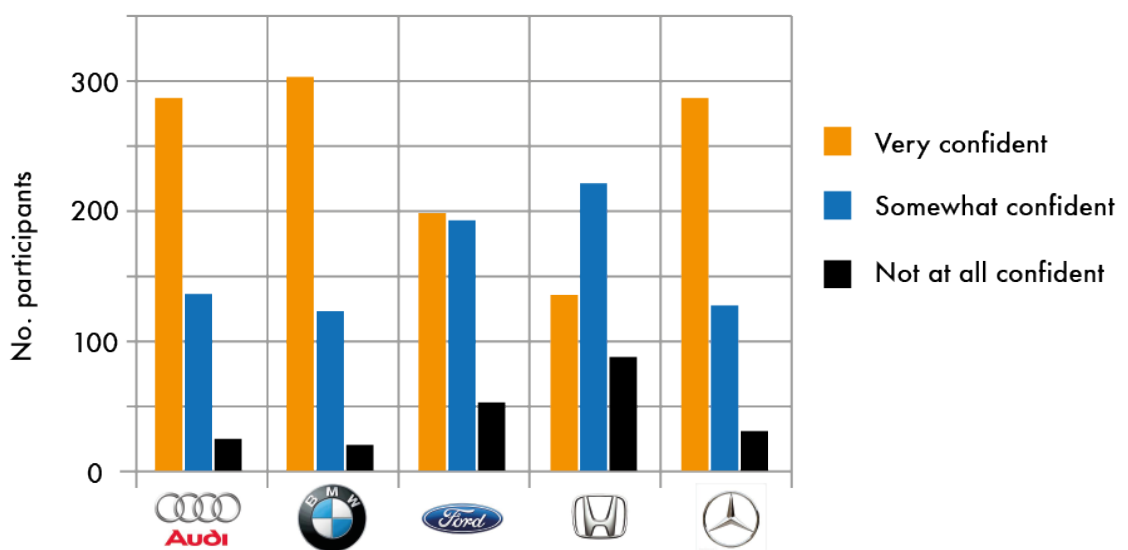


Figure 52 Participants' confidence in recognising different vehicle brands

6.2.6 Influence of participants familiarity and exposure to vehicles on responses

A multivariate analysis of results was conducted including information gathered in the profiling stage of the survey. This was done to ascertain whether the effect of a participant's prior knowledge of, and exposure to vehicles had any effect on their ability to identify vehicles. Broadly, of the participants correctly identifying vehicles, the proportions of age, gender, confidence in identifying brands and interest in styling reflected those of the total participant sample. As would be expected, it was found that participants who could drive and spent longer per week on the road answered a greater proportion (5%) of questions correctly than those who did not.

A further multivariate analysis was conducted to in order to investigate the distribution of correct responses on condition that a correct response to another question was achieved. For example, investigating distribution of responses to questions on vehicle segment where participants had correctly answered questions on vehicle brand. This was done to investigate whether participants associated certain vehicle segments or characteristics with brands when attempting to answer questions. The three possible combinations of two feature categories (brand and character, brand and segment, character and segment) were reviewed for each of the five vehicles used in the study. The distribution of correct responses is illustrated in Figure 53.

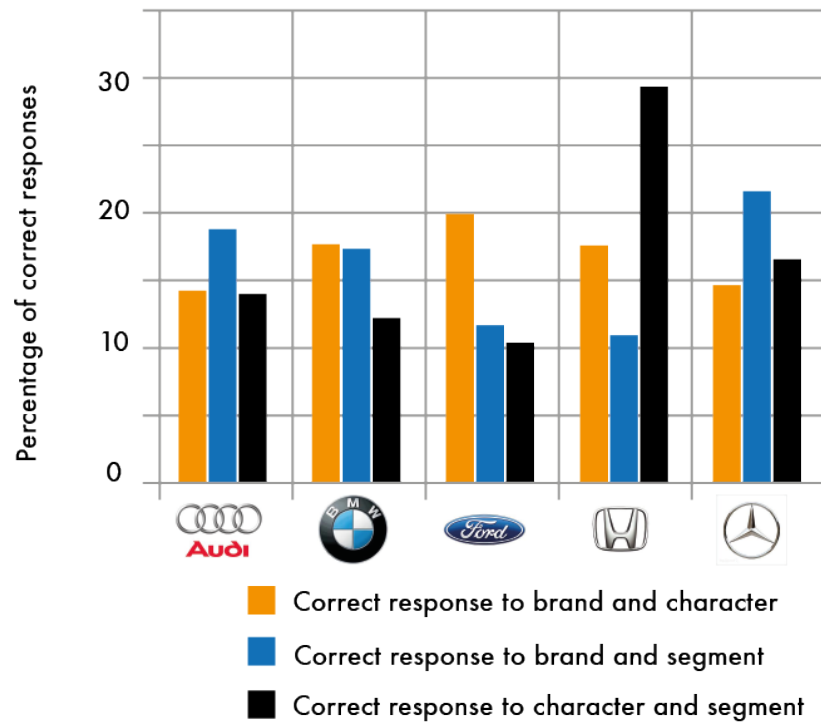


Figure 53 Multivariate analysis on responses to different types of question

As different vehicles were shown to participants a different number of times during the surveys, correct responses are shown as a proportion of the total number of responses to each vehicle. Based on Figure 53 it can be seen that there is no clear trend for participants to consistently answer one type of question correctly having answered another type of question correctly. For example, participants do not always identify segment correctly if they identify brand correctly. This is also demonstrated in that the proportion of correct responses is mirrored by the overall percentage of correct responses to character and segment shown in Figure 53.

6.3 Observations

Key observations from the results are now summarized.

- 1. The number of correct responses is not proportional to the number of feature categories included in each image.
- 2. There are more correct responses to questions posed with respect to front views and less correct responses with respect to side and rear views

- 3. Participants appear to find it harder to recognize vehicle segment and vehicle character compared with their ability to recognize brand
- 4. No obvious relation exists between side and rear views of the same vehicle and feature categories.
- 5. Images which return the greatest number of correct responses to brand are of the front view and include the 'Graphics' feature category.

When looking at results, it can be seen that there is no obvious pattern as to which vehicles and combinations of feature categories are consistently recognized by participants (save for those including explicit aesthetic features). On the contrary there is significant variation in number of correct responses (3% - 90% correct responses to different decompositions). This variety in responses suggests that certain images and thus combinations of features inspire different levels of recognition in participants indicating that the information communicated through the simplified two dimensional line form is rich enough to elicit correct responses from participants. Thus, although the representations of vehicles suffer from a relatively high level of abstraction, they can still be correctly identified.

6.4 Concluding remarks

This chapter presents the testing of the visual decomposition approach proposed in the previous chapter (5). In order to do so five vehicles were visually decomposed into constituent features then grouped into categories such that fair comparisons could be made. As well as testing the visual decomposition approach this was done to better understand the influence of feature geometry on product appearance and visual branding. This was achieved through the use of a web based survey in which images of vehicles visually decomposed into different feature categories were shown to respondents.

Results and subsequent observations from the web survey are now used to draw conclusions relating to the visual decomposition approach and the relationship between feature geometry and visual branding for the vehicles investigated.

The first key conclusion is that different combinations of feature categories have different potency in representing brand. The graphics feature category holds the greatest potency in representing brand. This was shown in participants' responses to images of the front view that included 'Graphics' (headlights and grille detail) producing far more correct responses than those without. Due to the varying potency of different geometries it can be further concluded that it is not the sum of information included in feature categories that influence responses but the potency of geometries included. With respect to objective II this conclusion demonstrates an example of increased understanding of the relationship between visual branding and feature geometry through the application of the visual decomposition approach. The implication of this is that the tool can be used to provide an indication of the resolution of feature size or relative prominence that is most potent in representing brand.

Secondly it is concluded that the proposed approach of visually decomposing images of products into feature categories was successful in exploring the relationship and influence of different features with/on visual branding. This was demonstrated by the distribution of correct and incorrect responses over the course of the survey in response to different combinations of features. This also indicates that the representation of products adopted for this study (2D line representation) contains an appropriate amount of detail for consumers to correctly identify brand. Based on this conclusion, it is contended that objective I has been achieved and validated.

Thus the major contribution to the thesis from the work reported in this chapter is in insights gained with regard to the influence of different features on the recognition of brand and more importantly in the validation of the visual decomposition approach. While it is shown that the decomposition strategy is useful in providing some insights on visual branding in product appearance, these insights are qualitative by nature. Hence there is a need for the further research into the use of the approach to apply quantitative analyses of appearance, addressed in the following chapter.

7 BEAUTIES AND BEASTS: EXPLORING AN APPROACH TO MEASURE AND COMPARE APPEARANCE

This chapter reports a scoping study into the use of quantitative measures to characterize and measure features in appearance. As such it reports the first steps in answering RQ2 (how can feature geometry be used to measure and compare product appearance). Thus this chapter also addresses the need for quantitative assessment of appearance stated in the previous chapter. The title ‘Beauties and Beasts’ is used as the study uses rules of classical beauty and proportion as a basis to explore characterization or differentiation between human faces and fictional characters using feature geometry

The chapter begins by discussing the rationale for using human faces and not vehicles as the subject of the study. One of the main reasons for using faces is the existence of geometric guidelines that define the position and proportion of features. These guidelines form the basis of a set of ‘rules’ or measures applied to characterize human features. The visual decomposition approach proposed in chapter 5 and tested in chapter 6 is then adopted as the first part of the experimental method used in the study. This approach is supplemented by the development of software that is used to apply rules to features generating measurement data for feature geometry which is subsequently reviewed.

The major conclusions drawn from the study include: further guidance for the use of photographs as the base visual material within the visual decomposition approach, a requirement for more holistic measures for assessment, and consideration of the nature of features with respect to their definition in the visual decomposition process. Hence the major contribution from the work included in this study is in the provision of insights to be considered in the further use and development of methods to quantitatively assess appearance.

7.1 Key aims of the study

The primary objective for conducting this pilot study was to produce a tool with the capability to read in information from industry standard graphics and photo editing software, plot key geometries, and provide a platform on which key geometries may be assessed on a quantitative basis thus addressing objective III.

The secondary aim of the study, having developed a tool was to demonstrate the capability of such a tool to produce measurement data, based on measures applied by the user, from which comparisons in geometries may be made addressing objective IV.

Outside of these two primary aims, this pilot study offers an opportunity to gain insights and feedback on the proposed method for decomposing/isolating and investigating aesthetic features with respect to brand. The pilot study is a point at which the isolation, tracing and potential measures proposed may be exercised in a range of instances, thus unforeseen difficulties can be identified.

7.2 Subject Material: faces

In this particular study the human face is used as the subject of analysis. For this purpose the face is defined as the front part of the head, from the forehead to the chin, and containing the eyes, nose, and mouth. The face was chosen for the following reasons.

Firstly there are pre existing ideas on measures that define dimensions and location of features of the human face with respect to the outline. These are discussed further in 7.3. These then can be used to test the ability of the measurement data output by the tool to differentiate in appearance.

Secondly there are some geometric similarities between the major features of the face and of vehicles. These include symmetrical and centrally located features about the vertical axis in both shapes and position. For example the headlights and eyes are oriented symmetrically about the centre-line of the outline, while other features such as daylight opening (DLO), or grille, and the nose and mouth are symmetrical about their vertical axes.

Finally there is acknowledgement of the likening/identification of human facial expressions in the front of vehicles (Windhager et al., 2012, Landwehr et al., 2011). Thus there is an element of general interest in the use of faces in this study.

7.3 Measures of facial proportions

The study into geometric proportions and aesthetics is said to be an ancient fascination (Fett, 2009). The first documented studies into geometric proportion and aesthetics conducted by Polycleitus and Vitruvius whose canons propose a number of proportional relationships in nature, art and architecture (Naini et al., 2006). These form the basis of the measures adopted in this chapter/study. Artists, most notably Leonardo Da Vinci used these classical proportions or guidelines in their studies of human geometry (Naini et al., 2006, Richter, 1952). The reason for such a focus on Da Vinci's study was that this was the first published material in which the Vitruvian proportions were brought together into one drawing/graphical form. Previous to this study the canon of proportions was a list of proportions. An extract translated into English is included

....a third part of the height of the face is from the bottom of the chin to bottom of the nostrils; the nose from the bottom of the nostrils to the line between the brows, as much; from that line to the roots of the hair, the fore- head is given as the third part....

(Vitruvius, De Architectura. III, I, 2-3, ed. and trans. E Granger. London and Cambridge, MA: W. Heinemann/Harvard University Press, 1970, vol. 1, pp. 159-161. Extract taken from (Laurenza, 2006)

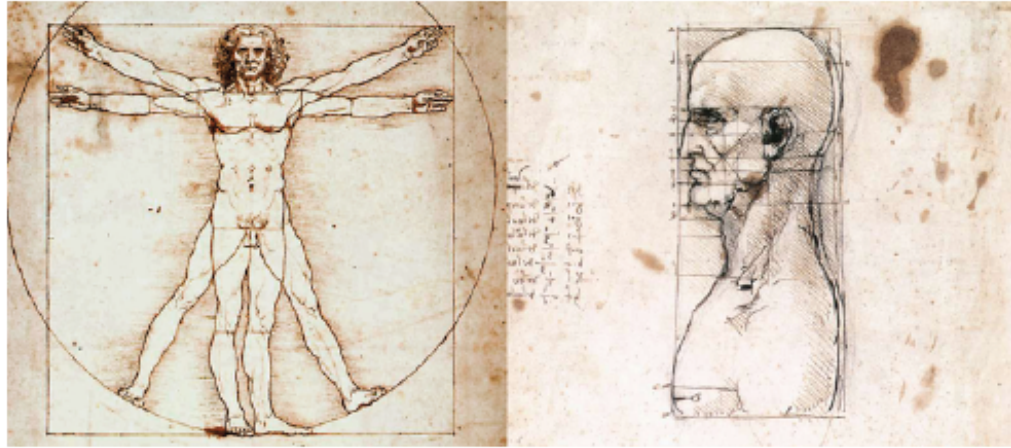


Figure 54 Da Vinci's drawings created as part of his study into the Vitruvian canon

The sketches from Da Vinci's studies and the key proportions they infer are still used as a guideline for human proportion in fine art/drawing (Barber, 2006) and also in fields of orthodontistry, aloplastic and reconstructive surgery (Jefferson, 2004, Mommaerts and Moerenhout, 2010, Naini et al., 2006). Details of these proportions are presented in sections 7.3.1 - 7.3.4.

Closely related to the study of human facial proportions is the study of facial beauty and the golden ratio or section (1:1.618). Da Vinci does not make any direct reference to the golden ratio in his studies of Vitruvian proportions (Laurenza, 2006, Richter, 1952). It has however been demonstrated that within the proportions Da Vinci set out, there are a number of spatial relationships/proportions that adhere to the golden ratio. Atiyeh and Hayek (2008) state that debate over what constitutes human beauty has raged since the birth of philosophy. In their review of research in this topic they conclude that adherence to the golden ratio can be used as a guide to a well proportioned face. However, the concept of beauty is too subjective to be fully defined through the golden ratio.

The study presented in this chapter does not attempt to contribute to the debate on aesthetics by drawing conclusions on the beauty of the test photos based on facial proportions. The proportion measures are used as they have been shown in literature as being an accurate guide for the position and proportion of facial features. The availability of pre-existing measures means comparisons can be made between proportions and measurement data output from the developed software to validate the software and experimental method.

7.3.1 Proportions used in the pilot study

Based on art fundamentals and surgical facial proportions that draw on Da Vinci's studies, Figure 55 has been constructed which outlines the key proportions that form the rules against which facial feature geometry is compared. Sections 7.3.2 - 7.3.4 detail the proportions used to form rules and the precise geometric measures applied in order to make comparisons.

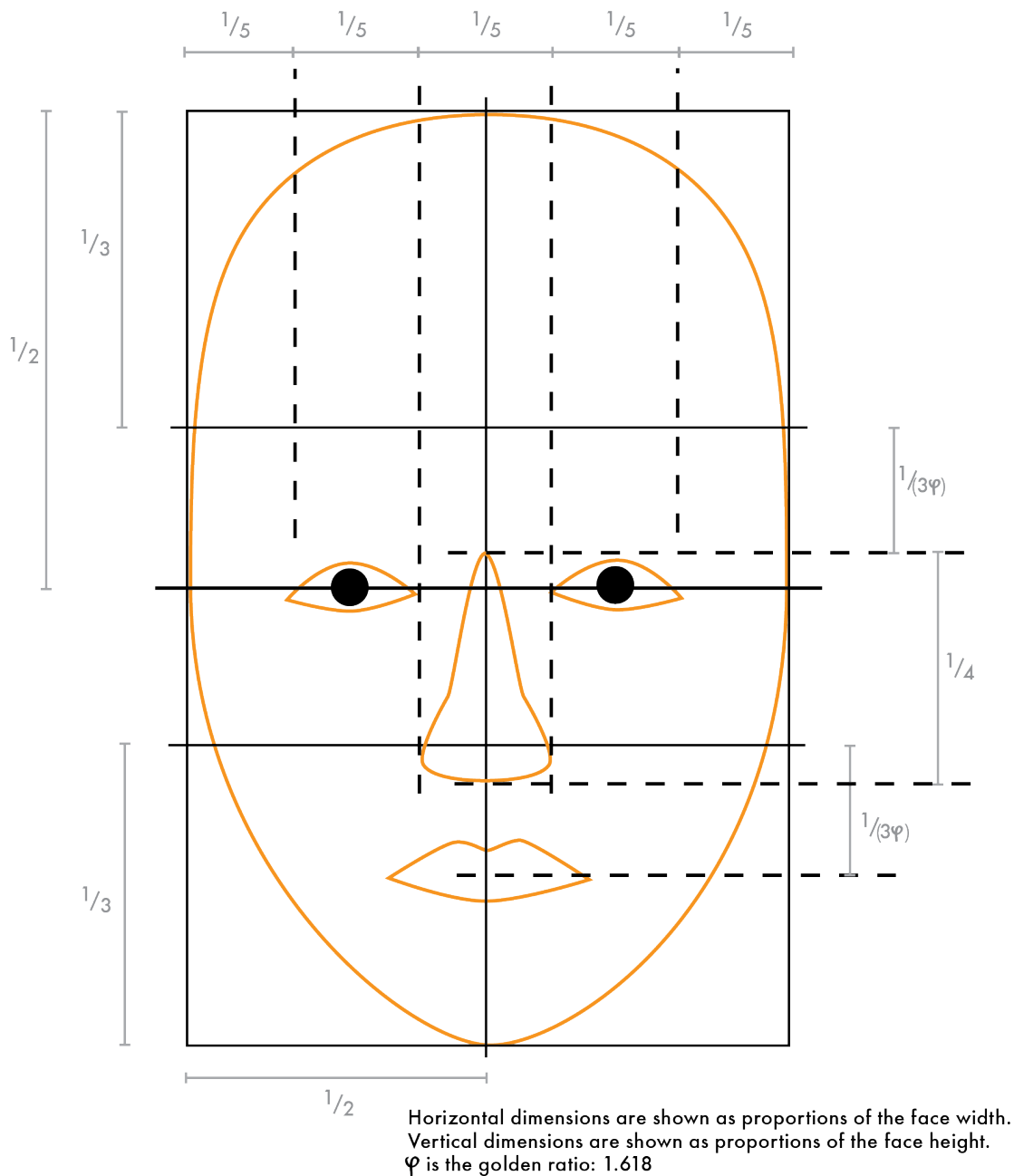


Figure 55 Illustration of guideline proportions

The proportions that will be used in this study to form rules are proportions with respect to the overall dimensions of the face. The features eyes, nose and mouth will have a dimension defined with respect to the face dimensions and their position in the X and Y-axes defined with respect to the face. From Figure 55 it is also possible to define features with respect to each other. For example the width of the nose may be defined as one fifth the width of the face or as the same width as an eye. By defining all dimensions and positions as a proportion of the overall face size, measures become independent of absolute size in the photograph and may thus be easily compared.

7.3.2 Eye measures & rules

Figure 56 illustrates the measures and rules that define the position and size of the eyes, and the calculation to test the proximity rules.

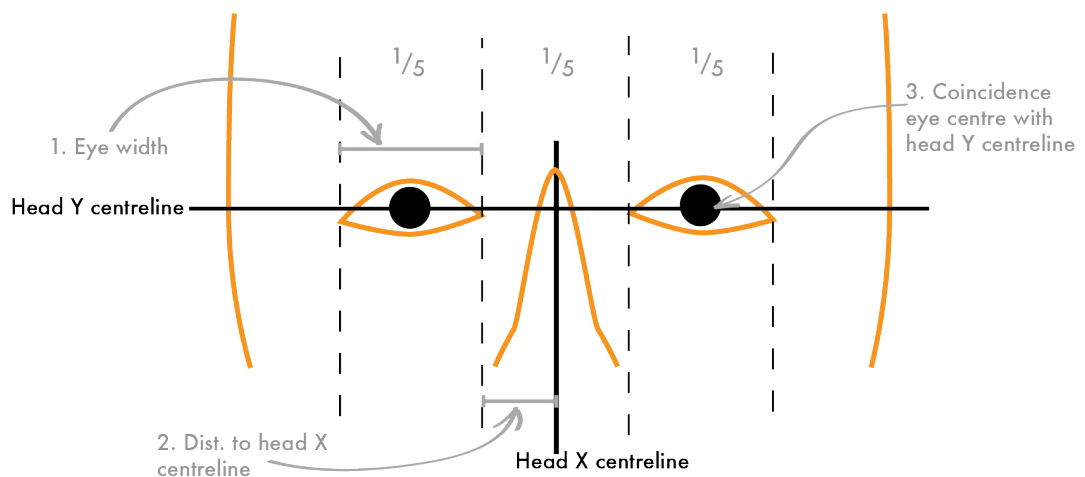


Figure 56 Measures that define dimension and position rules with respect to the size and orientation of the eyes

Dimension rule: Eye width is one fifth the face's width

$$\left(\text{Eye width} - \frac{\text{Face width}}{5} \right) \times \frac{1}{\text{Face width}}$$

Position rules: The inner most point of the eye is one tenth the face's width from the Face's horizontal centre

$$\left(X \text{ max or } X \text{ min} - \left(\frac{\text{Face width}}{2} \pm \frac{\text{Face width}}{10} \right) \right) \times \frac{1}{\text{Face width}}$$

Horizontal centreline of the eye is coincident with the face horizontal centreline.

$$\left(\frac{\text{Eye height}}{2} - \frac{\text{Face height}}{2} \right) \times \frac{1}{\text{Face height}}$$

7.3.3 Nose measures & rules

Figure 57 illustrates the measures and rules that define the position and size of the nose, and the calculation to test the proximity rules.

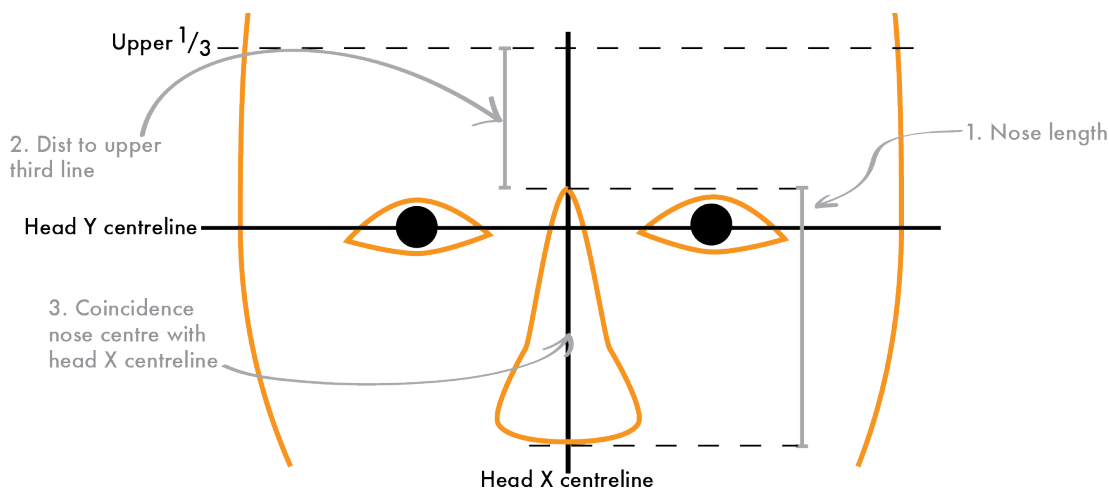


Figure 57 Measures that define dimension and position rules with respect to the size and orientation of the nose

Dimension rule: The length of the nose is one quarter the length of the face

$$\left(\text{Nose height} - \frac{\text{Face height}}{4} \right) \times \frac{1}{\text{Face height}}$$

Position rules: The root of the nose is the golden ratio the golden ratio one third the face above one third the face height

$$Y_{\text{max}} - \left(\frac{2 \times \text{Face height}}{3} - \frac{\text{Face height}}{3(1+\phi)} \right) \times \frac{1}{\text{Face height}}$$

The X (vertical) centre line of the nose is coincident with the X centre line of the head

$$\left(\frac{\text{Nose width}}{2} - \frac{\text{Face width}}{2} \right) \times \frac{1}{\text{Face width}}$$

7.3.4 Mouth measures

Figure 58 illustrates the measures and rules that define the position and size of the mouth, and the calculation to test the proximity rules.

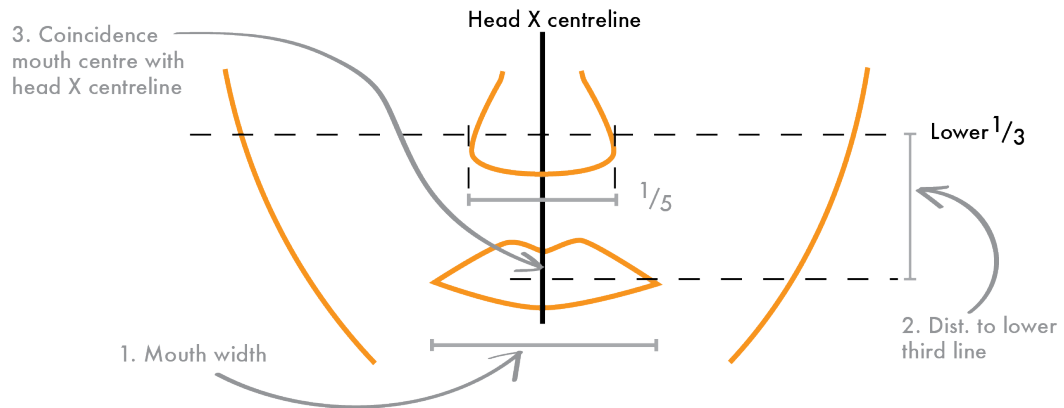


Figure 58 Measures that define dimension and position rules with respect to the size and orientation of the mouth

Dimension rule: Mouth width is Φ one fifth the head's width

$$\left(\text{Mouth width} - \frac{\Phi \times \text{Face width}}{5} \right) \times \frac{1}{\text{Face width}}$$

Position rules: Mouth x (horizontal) centreline is 1-phi the third of the face height from the lower third line

$$\left(\frac{\text{Mouth height}}{2} - \left(\frac{\text{Face height}}{3} - \frac{\text{Face height}}{3(1+\Phi)} \right) \right) \times \frac{1}{\text{Face height}}$$

The X (vertical) centreline of the mouth is coincident with the X centreline of the head

$$\left(\frac{\text{Mouth width}}{2} - \frac{\text{Face width}}{2} \right) \times \frac{1}{\text{Face width}}$$

7.4 Experimental method

This section details the steps taken to apply the visual decomposition approach, in particular the generation of base visual material and tracing of features. A generic method to characterize and measure features is now proposed in Figure 59. The details of how this method is implemented to generate the experimental method adopted in this scoping study is now addressed.

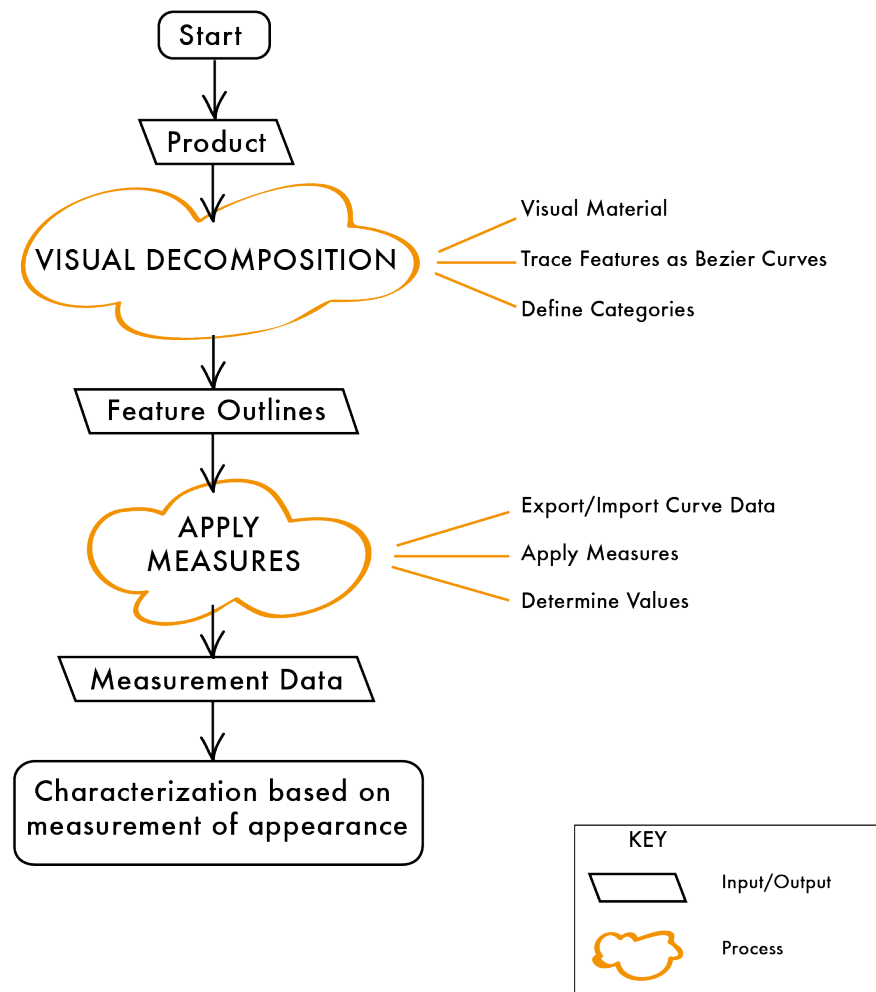


Figure 59 Generic method to characterize and measure features in appearance. This method forms the basis from which the experimental method adopted in this scoping study is derived

7.4.1 Visual decomposition: Visual material

A number of images were gathered from public pages of a research group (<http://www.bath.ac.uk/idmrc/>). From the complete range of images available, a primary vetting stage had to be undertaken. This was done to ensure that position of the heads in the photographs were similar and that subjects were looking at the camera.

It is thought that different expressions, or photos taken from one side can skew the position of features on the outline when isolated and traced. Following this vetting stage 21 images of faces were selected from 40.

Not all images were the same size when gathered, thus images were scaled to the same size (857x1068 pixels). This was done not to standardise the size of heads but to ensure similar resolutions for tracing features. All images were passport-style photographs, hence the face occupied the majority of the image in all photographs.

Along with the faces, images of four fictional characters were included. These characters were included as they were assumed to have exaggerated features compared with those of the human features. It was contended that the measures should be able to clearly distinguish these exaggerations from the human features.



Figure 60 Fictional characters used in the study

7.4.2 Visual decomposition: Tracing features

The first step in investigating and measuring feature geometry is to isolate features to define their geometry. This definition is achieved by tracing the outline of features from photographs. The outlines of the five features (left and right eyes are considered separately) to be traced are defined slightly differently depending on the feature. Outlines are defined as:

- *Face outline* – The outline of the head is traced by following the silhouette of the skull. In some cases the path of the skull is estimated where hair occludes the definition of the skull. The lower part of the head/face is defined by tracing the edge of the jaw.

- *Left and right eye outlines* – The eyes are defined by the visible difference between the eyelids and the eyeball.
- *Nose outline* – The nose is the most subjective feature in its definition. The lower portion of the nose is defined by the nostril wings (the outside of each nostril) and the septum. The upper portion (or root) of the nose is harder to define as there are no clear edges by which to identify it. Thus, to complete the upper bounds, the upper part of the nose (nasal root) is assumed to end approximately in line with the upper inner corner of the eye socket.
- *Mouth outline* – The mouth is defined by the visible difference in skin pigmentation between the philtrum and the upper lip and the chin boss (skin covering the chin) and the lower lip, also termed the vermillion border.

The tracing technique adopted for this study is the same as that used in the visual decomposition approach (section 5.2.2). Thus it is based on using chains of Bézier curves plotted over photographs to trace feature outlines. To trace facial features, the face and nose outlines used six control points and the eyes and mouth used four points. This number of points was thought to provide enough detail to reasonably trace the features while not being too labour intensive.

7.4.3 Apply measures

Having traced features the image was exported in the drawing interchange or drawing exchange format (DXF). This format includes the mathematical data which describes each of the spline curves that represent features in a format which may then be read by another program. Furthermore the specifications of the DXF format are made public. This meant it was possible to easily locate the parts of the DXF file containing data describing the spline curves, and understand the format in which the curves were described.

Software was developed which imported and read the DXF files, extracting data describing the curves. From the curve data, the measures described in 7.3.2 - 7.3.4 were applied, and the results recorded in a file. This process was then repeated for each face contained in individual files. The complete experimental method adopted for this

scoping study is summarized in Figure 61 highlighting the steps where the visual decomposition approach is for use in this study.

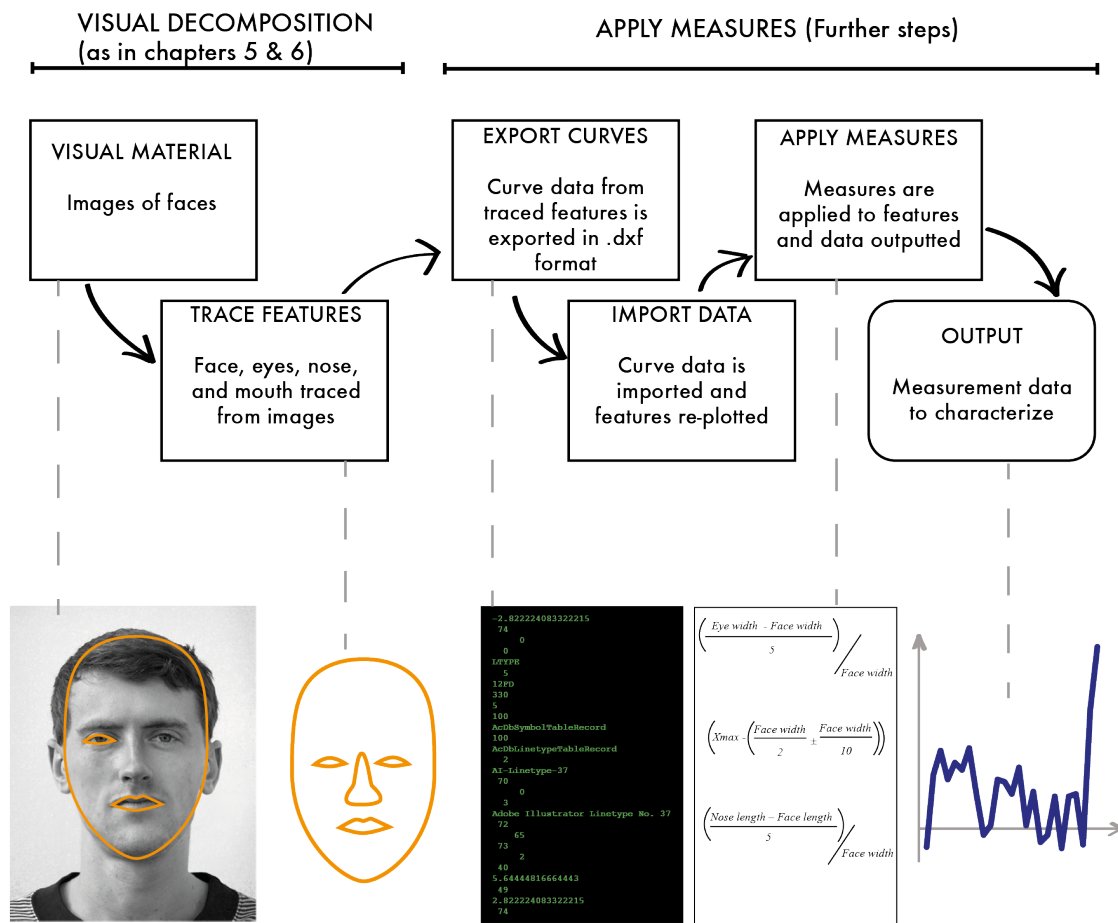


Figure 61 Summary of the experimental method adopted for the scoping study

7.4.4 Systematic error in tracing features

A test was carried out to assess the systematic error inherent in tracing of features. This test involved isolating and tracing the features in the same way as in the experimental method (7.4) but repeating the process on a single human head. Consideration of the systematic error is required to be able to ascertain whether variations in measurements between faces was not due to human error in tracing and isolating features. Calculating the range of measurements for features gave a value for possible error in the tracing of features. Values for systematic error are included in Table 5 - Table 7 and taken into consideration in results presented in Figures Figure 62 - Figure 65. The implications of error on results is discussed in section 7.6.3.

7.5 Results

The resulting data from application of measures are presented and discussed from the perspective of identifying or characterizing fictional characters' faces from the human faces based on feature geometry.

7.5.1 Identification of trends and differentiation of characters

Figure 62 summarises the difference in feature dimension from rules, it possible to see a clear trend in the difference from rules of features from human features and features from fictional characters. This is manifested in the significant difference between overall human feature range and character feature range. When reviewing the individual data ranges from comparison of head, left eye and right eye measures, (Figure 63), it can be seen that the numerical difference between human features and features of characters is clear. However when reviewing the numerical range difference from nose and mouth dimension comparisons (Figure 63), it is surprising to see that there is no significant range difference between human features and character's features. That is to say the character feature dimensions fall into the typical range seen in human feature dimensions.

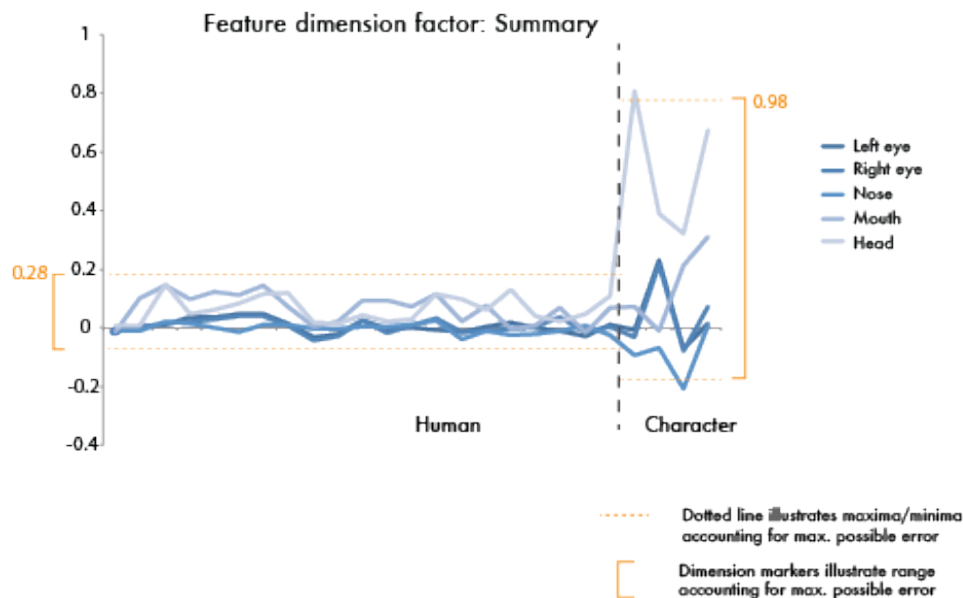


Figure 62 Difference in dimension from rules for all features

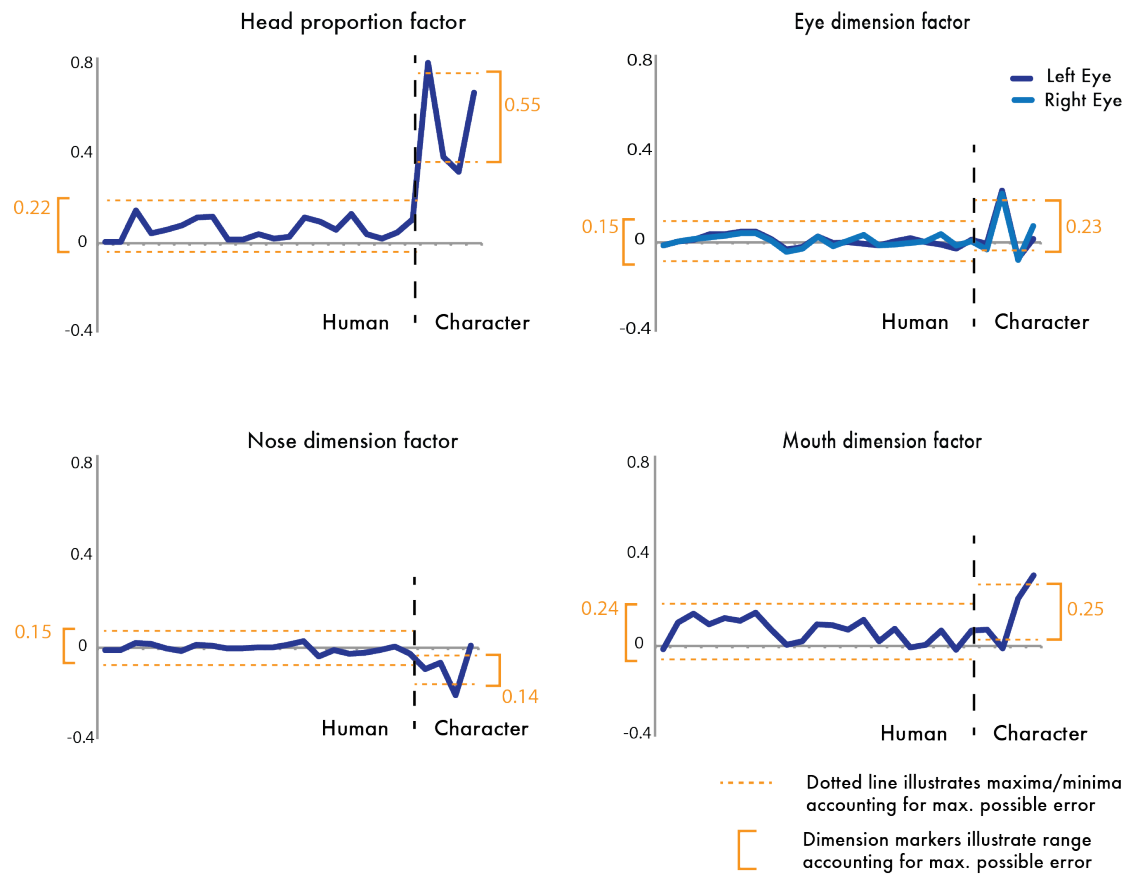


Figure 63 Individual feature dimension difference from guideline

Feature Dimension	Avg. Error	Human range	Character range	Human range + avg. error	Character range - avg. error	Difference incl. error	> Avg. error?
Head	0.036	0.142	0.489	0.214	0.417	0.203	TRUE
Left eye	0.036	0.078	0.309	0.15	0.237	0.087	TRUE
Right eye	0.036	0.081	0.297	0.153	0.225	0.072	TRUE
Nose	0.036	0.067	0.217	0.139	0.145	0.006	FALSE
Mouth	0.036	0.163	0.321	0.235	0.249	0.014	FALSE

Table 5 Summary of dimension data ranges with respect to possible error in different features

Table 5 compares the range in proximity to dimension rules against the systematic error associated with measures for each feature. It highlights that the range in systematic error associated with nose and mouth measures is too great to be able to reliably differentiate character faces from human faces.

Similar results can be seen when reviewing data from the position measures. It can be seen that it is not possible to differentiate characters from human heads when looking at position data from either the mouth or nose measures. This is illustrated in Figure 64

which shows the range in mouth and nose position for human faces is as large if not larger than that of the characters. This is also shown in the comparison of data ranges for human heads and all heads (human and character) in Table 6.

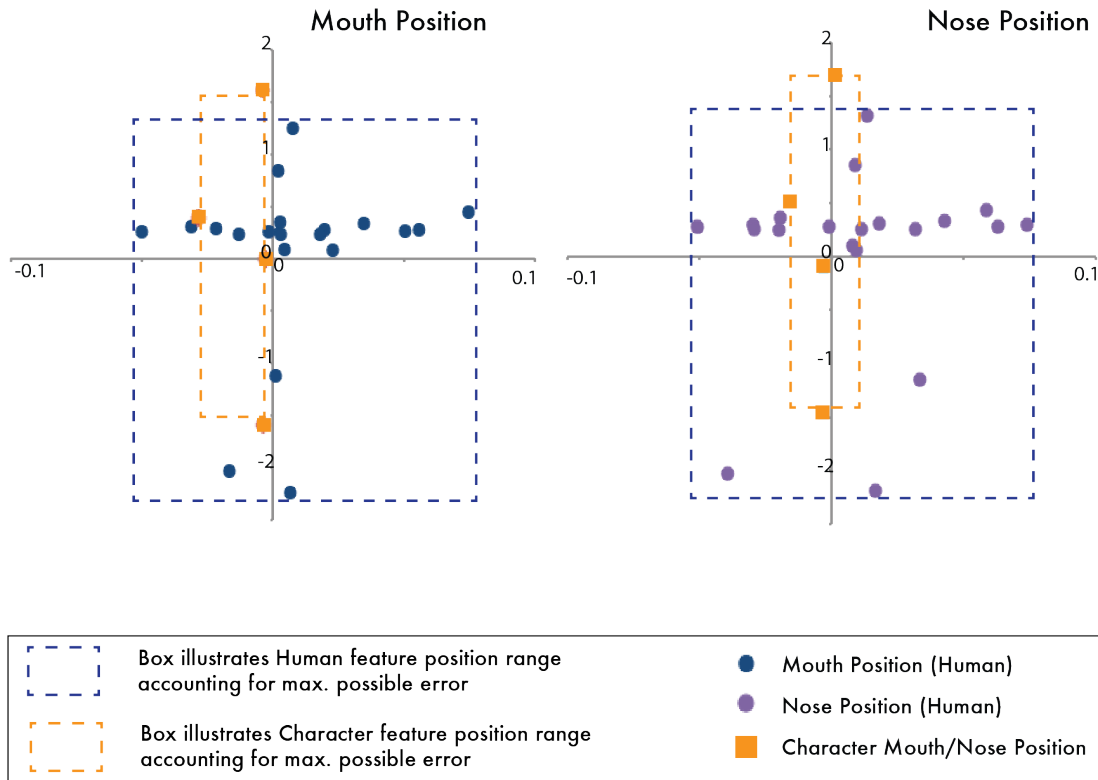


Figure 64 Mouth and Nose feature positions

Also of note from position measurements from the mouth and nose measures is the difference in range between the X position and Y position. The X position range is approximately one thirtieth (0.03) the range in Y position.

Conversely when observing the position data for both left and right eyes (Figure 65 and Table 6) the data range in both X and Y positions for both human eyes is relatively small. Taking into consideration the error in eye position, the character eye data range of fictional characters is still substantially greater than the human eye data range. Thus it can be said that the eye position measures are capable of differentiating characters' eyes from human eyes.

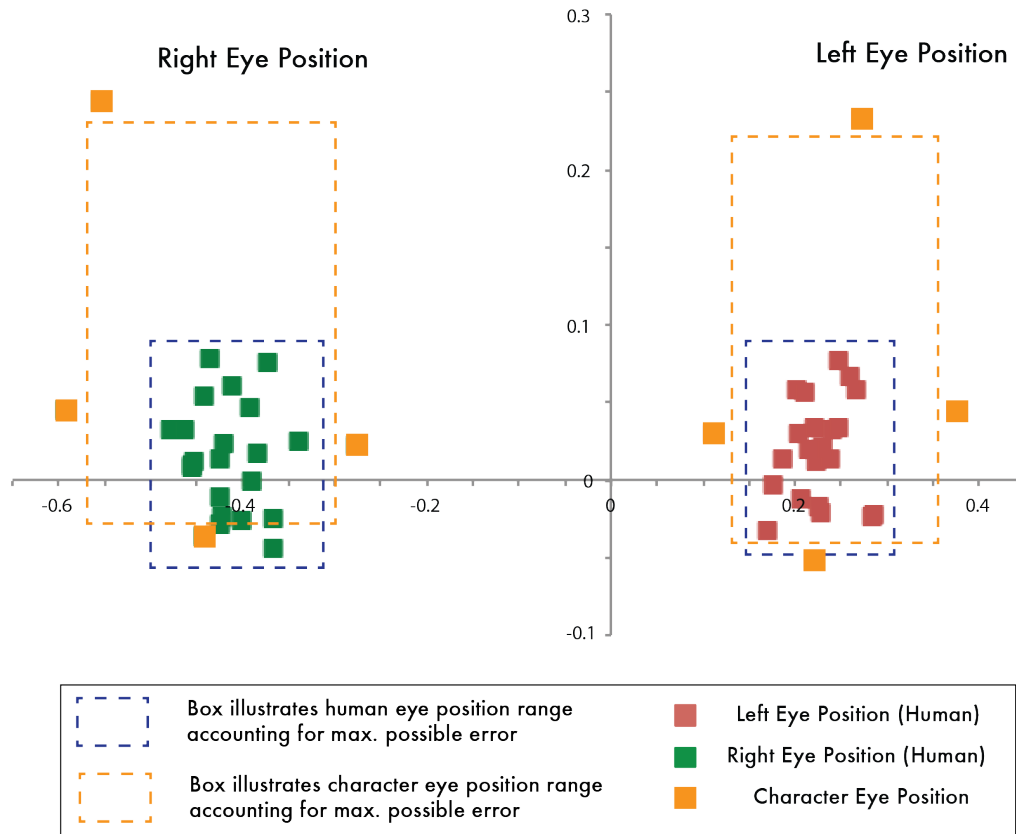


Figure 65 Eye feature positions

Feature Position		Avg. Error	Human range	Character range	Human range + avg. error	Character range - avg. error	Difference incl. error	> Avg. error?
Left eye	X	0.019	0.120	0.260	0.158	0.222	0.063	TRUE
	Y	0.012	0.130	0.200	0.154	0.176	0.022	TRUE
Right eye	X	0.014	0.140	0.320	0.167	0.293	0.125	TRUE
	Y	0.012	0.120	0.220	0.144	0.196	0.051	TRUE
Nose	X	0.018	0.120	0.017	0.156	-0.019	-0.174	FALSE
	Y	1.846	3.500	3.160	7.193	-0.533	-7.726	FALSE
Mouth	X	0.014	0.124	0.026	0.151	-0.001	-0.152	FALSE
	Y	1.839	3.480	3.200	7.158	-0.478	-7.636	FALSE

Table 6 Summary of position data ranges with respect to possible error in different features

7.6 Discussion

The results from the application of the method are now discussed with respect to the method and measures used, implications for use with respect to product appearance and in particular vehicles and error associated with the the software implemented to measure geometry from decomposed features.

7.6.1 Implementation of software to measure feature geometry

From the variance in data outputted from different measures and also the error associated with different measures, it is possible to highlight drawbacks in the approach to measure feature geometry and propose improvements. In the instance of the dimension measures it is seen that the data range for eye dimensions is smaller than that of other measures. This is also the case for eye position measures when compared with other position measures. A possible cause of these differences is suspected to be related to the ease of tracing and isolating the eyes compared with the nose mouth and head. In the case of the human faces, an outline of the eye may be easily traced due to the visible difference seen between the eyeball and the surrounding skin of the eyelid. In the case of the nose dimension, it was harder to define the edge of each nostril wing. Similarly with the head outline, hair made it harder to judge the precise outline of the skull.

The measures for X and Y position are defined by the midpoints in total feature width and height respectively. An exception to this is the Y position of the nose which is defined by the uppermost Y position. In order to create this bounding box the user, although not directly measuring feature dimensions, must make an estimate of them. In the case of the nose y position, it is thought that the substantial data range is due to the measure being based from the upper extrema (Y max) of the traced outline (see Figure 57). When tracing the nose it was found to be difficult judge the root of the nose. It is thought that this difficulty resulted in a large range in the upper limit of nose outline and consequently a large range in the measurements for the nose Y position.

In this approach the complete outline shape of features is traced, yet measures applied only refer to certain key points. This means that there is further geometric information available/created that is not measured. By considering the complete shape rather than key points on/of the shape, a more extensive and accurate set of data defining feature geometry can be collected.

In the case of the mouth position, the estimation of the mouth shape was less difficult and subjective than that of the upper nose boundary. This was due to the relative ease in using the change in skin tone between the lips and surrounding skin. Thus it is thought that the large range in the measurements was not due to subjectivity in tracing the outline of the mouth. Moreover it was due to the variation in mouth shapes caused

by a variety of facial expressions of subjects in photos. Where the shape of the eyes and nose remain relatively similar, the shape of the mouth varied with different expressions.

A final factor considered to impact the data ranges outputted from nose and mouth measures was the angle of the head in the photos. While only photos where subjects were considered to be looking directly at the camera were used, there was little consideration for whether the head was pitched forward or backward (chin up or down). It is thought that as the eyes lie close to the vertical centre of the head, this pitching would have little impact on the eye measures. However as the nose and mouth are further from the centre this pitching could have a relatively significant impact on position relative to the perceived shape of the face outline.

7.6.2 Implications for measuring product appearance

In terms of how points discussed on the methodology feed back on the application of this technique analyse other products and in particular vehicles, a number of key points are made. The first key point that can be made concerns subjectivity in tracing features. Data outputted shows that, when applying the methodology used in this study, features that require a greater level of subjectivity in order to be traced are unlikely to be able highlight trends and or differentiate outlying features. This is due to systematic error in the judgment of feature outline.

The second key point is the requirement for standardisation in source photographs. In the source photographs used for this study there was a low level of consistency in the position and expression of subjects. In some respects this is not a key issue when considering this technique for application to cars as they are not variable or morphous in the same way as a human face. In further experimentation there may well be a requirement to use photos in light of restricted access to such CAD data from vehicle manufacturers. Thus it is noted that the requirement to position subject vehicles and use the same lens and camera settings are essential in being able to minimise error. Guidelines for best practice in this conducting this type of experiment can be sourced from literature reporting research into photogrammetry (the formal name for taking measurement of objects based on photographs).

7.6.3 Error

When reviewing the range of data output from the error test described in (7.4.4) it can be seen that, for some measures, error was substantially great such that no characters' features could not be reliably differentiated from human features (Table 5 - Table 6). In order to further investigate the error in this technique a further error assessment was undertaken. An image was taken at higher resolution (1424x1976 pixels compared with the test images 857x1068) with the subject looking as directly at the camera as possible maintaining an even expression. The head, left eye and nose features were then traced using a greater number of control points (up to double) where required. Less features (face, left eye and nose) and less repetitions (10) were included due to the increased time required to trace features at a greater level of detail. A comparison of the data ranges output from both error tests is included in Table 7.

	Head prprtn		Left Eye dimension		Left Eye pos.(X)		Left Eye pos.(Y)		Nose dimension		Nose pos.(X)		Nose pos.(Y)	
	SD	Range	SD	Range	SD	Range	SD	Range	SD	Range	SD	Range	SD	Range
Test 1	0.0121	0.0478	0.0083	0.028	0.0057	0.0192	0.0031	0.012	0.0071	0.038	0.004	0.014	0.42	1.839
Test 2	0.0025	0.0073	0.0033	0.0110	0.0039	0.0132	0.0005	0.0016	0.0120	0.0360	0.0012	0.0038	0.0540	0.1860
% error reduction	79.3	84.7	60.2	60.7	31.6	31.3	83.9	86.7	-69.0	5.3	66.7	72.9	87.1	89.9

Table 7 Comparing results from first and second error tests

From Table 7 it can be seen that by increasing image resolution, unrestricted number of control points and improving the positioning of the subject can dramatically reduce error. This is particularly the case in the nose dimension and position factors.

Findings from this comparison of errors further reinforce the requirement for improved and standardised subject placement. It also demonstrates the need for high-resolution images (and appropriately high resolution display) on which to base feature tracings if error is to be minimised. Thus this shows that subjectivity required to make tracings is reduced through the use of high-resolution images and increased number of control points.

7.7 Concluding remarks

The aim of conducting the research reported in this chapter was to address the need for objective assessment of appearance by exploring the characterization and measurement of features, and thus in order to achieve this create a software tool to apply measures to appearance.

This was achieved by visually decomposing images of human faces and those of fictional characters. Software was then developed to apply measures (quantitative assessment) based on classical rules on facial proportion. Resulting measurement data was then reviewed to assess the use of measures to identify and thus characterize the fictional characters from the sample of faces investigated.

The primary conclusion that may be drawn from the experiment is that the method was successful in being able to make comparisons between a particular geometry from a group of features and their adherence to geometric rules. In other words this approach was able to assess distinctiveness or deviation of certain feature geometries from a sample using geometric measures. This was demonstrated through the ability to identify/characterise fictional characters' faces from a sample of human faces.

In reviewing data it was seen that, in a number of cases, comparison of geometries with respect to a rule individually would not always identify characters faces. It is thus concluded that measures should be applied and reviewed holistically or collectively and in doing so produce more accurate and extensive information when characterizing features. From the results it can be concluded that there is a particular need for measures that consider the shape or contour of traced features.

A number of conclusions may be drawn on the method adopted. Reviewing systematic error in the approach showed that accurate tracings can be achieved by using high resolution images of products (over 1500x2000 pixels) in which the product or subject takes up the majority of the image. It is also shown that not limiting the number of control points when tracing features also creates more accurate feature tracings and hence more reliable measurement data.

Furthermore it was shown that tracing features which require a high degree of subjectivity to define results in a high level of systematic error such that tracings

produced are not of a high enough accuracy to produce reliable measurement data. Therefore it is contended that, when following the steps of the method proposed and implemented in this scoping study, reliable results can only be achieved when exploring features with easily defined boundaries.

In terms of the contribution to the thesis, the conclusions firstly validate the approach proposed in this chapter as a basis for measurement, comparison and characterization of appearance while also providing some guidance on improvements. However, conclusions also present the need to investigate more holistic measures of appearance and strategies to define feature boundaries in order to reduce subjectivity and increase repeatability in feature tracing. Thus the following chapter is used to explore these issues.

8 PROPOSED METHOD TO MEASURE SIMILARITY IN PRODUCT APPEARANCE

The method proposed in this chapter presents a new set of measures (feature analyses) that draw on the measures proposed and the insights gained from their application in chapter 7. This is, namely the need for more holistic analyses that consider feature shape/contour.

The proposed method aims to achieve the measurement of similarity in appearance in three stages. The first stage, visual decomposition is the same as that proposed and applied in chapters 5,6 and 7. Second feature geometry is assessed through the application of feature analyses. The result of applying analyses is measurement data relating to features in product appearance. The third stage is to use measurement data to compare features across similar products by calculating similarities and differences in geometry, thus forming the basis for objective evaluation.

The chapter begins by discussing the development of the three analyses applied to measure feature geometry. Using a number of examples the interpretation of data resulting from analyses is discussed. Following interpretation, the approach used to determine the degree of similarity/difference between features across a range of products using results from analyses is detailed. The assumptions made in order to apply degree of similarity calculations relating to a base level of similarity in the products under analysis is also discussed. Finally the framework in which the analyses fit in order to apply the method is discussed. Much of the framework of the method is based on the visual decomposition technique proposed and tested in chapters 5 and 6, while the software used is the same as that developed in 7.

8.1 Analyses of product appearance

A set of analyses for product appearance are now proposed. The basis for these comes

from the measures used in the previous chapter. Crucially a further analysis is also proposed which addresses the need to consider shape. Hence three analyses are used to evaluate individual features and their interrelationships within overall product appearance based on product geometry. These are: feature proportion analysis, feature orientation analysis and feature shape analysis. The results of applying all analyses gives numerical data on a product's appearance that can then be used to derive what is referred to herein as the degree of similarity between products. Figure 66 introduces the three types of analysis using a generic product as an example. Sections 8.1.1 - 8.1.3 present the three analyses in detail and discuss the nature of the resulting data.

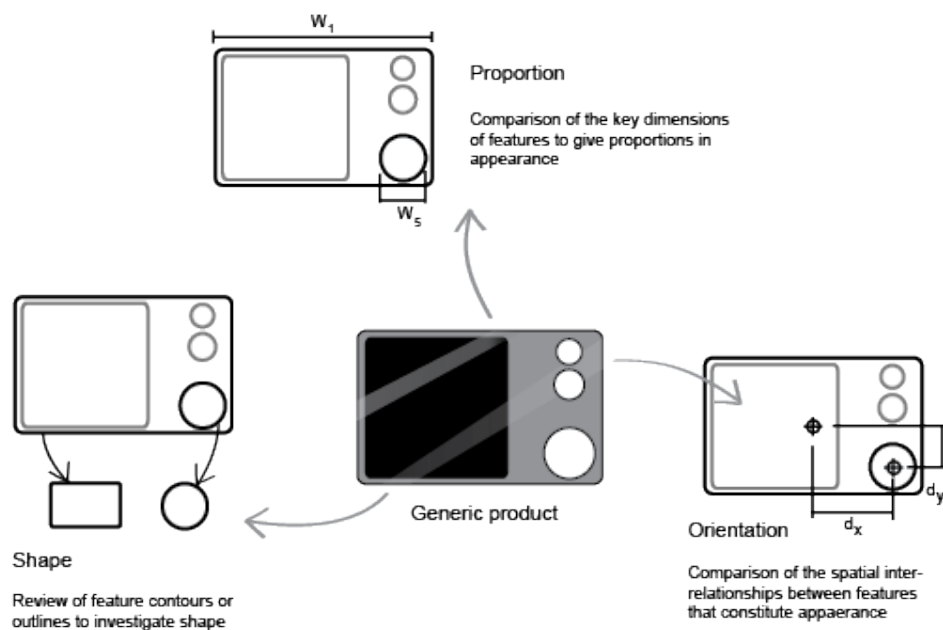


Figure 66 Summary of analyses used to evaluate appearance

8.1.1 Feature proportion analysis

In feature proportion analysis, area, perimeter, length and width of features are recorded as a proportion of the other features within the product. This analysis requires little further interpretation as proportions are immediately calculated and relatable to interrelationships of feature geometry. Patterns in a given proportion may then be reviewed and compared with other products by plotting values for specific proportions between features across a range of products. The relationship between proportion analysis data and product features is illustrated in Figure 67. In this case the proportion

between the widths of two features (W_1 and W_5) is calculated and plotted along with the same proportion from a range of other products.

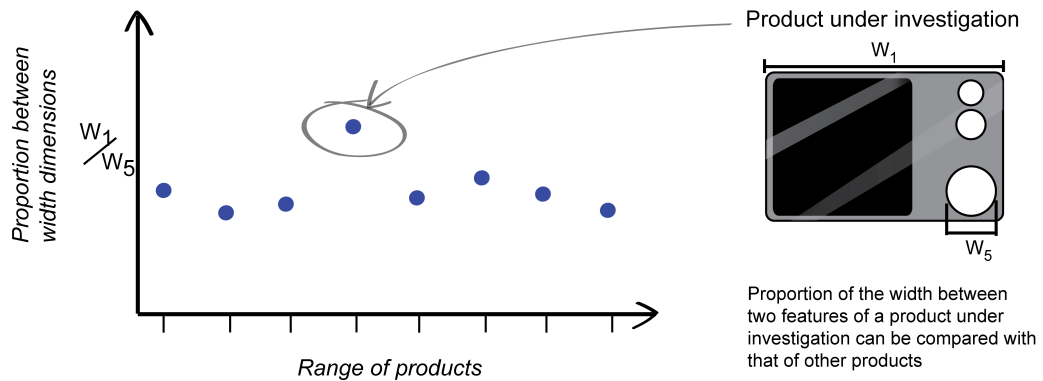


Figure 67 Illustrating feature proportion analysis

8.1.2 Feature orientation analysis

As with proportion analysis data, orientation analysis data is relatively self-evident and requires little interpretation. Orientation data includes coordinates for the position of a feature's centre of gravity of the bounding curve (henceforth referred to as centroid) and X and Y maxima and minima values. The axes against which these are plotted are defined by the centroid of a given feature. In the example included, the axes are based on the 'outline' feature. These coordinates may then be plotted for all features of the product being analysed. Given these coordinates, the variation in position can be analysed across a range of products. The relationship between orientation analysis data and product features is illustrated in Figure 68. Here the location of the axes used to plot feature positions is shown with respect to the product image. Lastly the position features' centroids, maxima and minima are shown plotted on the axes.

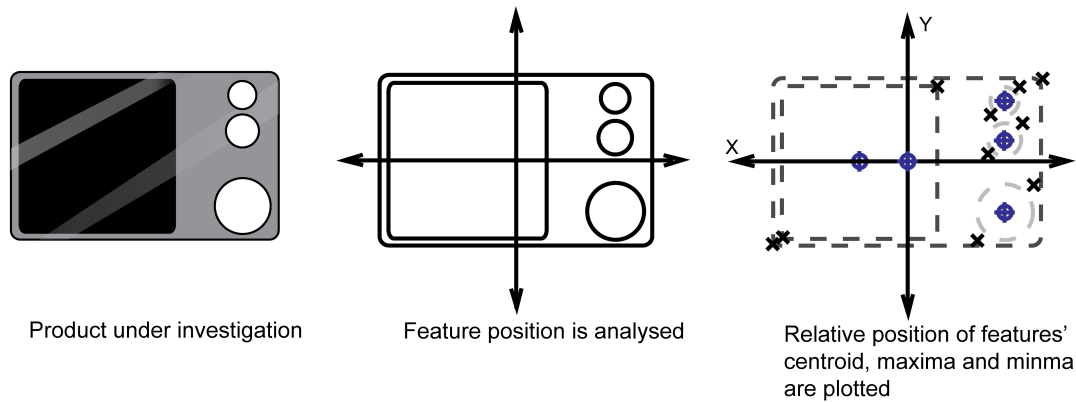


Figure 68 Illustrating orientation analysis

8.1.3 Feature shape analysis

Shape analysis is derived by calculating the radial length between a feature's centroid and a given point on the feature's outline. This is repeated incrementally for a given number of points evenly spaced over the complete feature outline. The values for radial length may then be plotted for each incremental point. Unlike the proportion and orientation analyses, the shape analysis is less straightforward in terms of relating the feature shape investigated and the plotted shape analysis data. Figure 69 shows an example of a shape analysis applied to a feature of the generic product shown in previous figures. To further illustrate the analysis and its interpretation, Figure 70 shows examples of a shape analysis applied to three simple shapes.

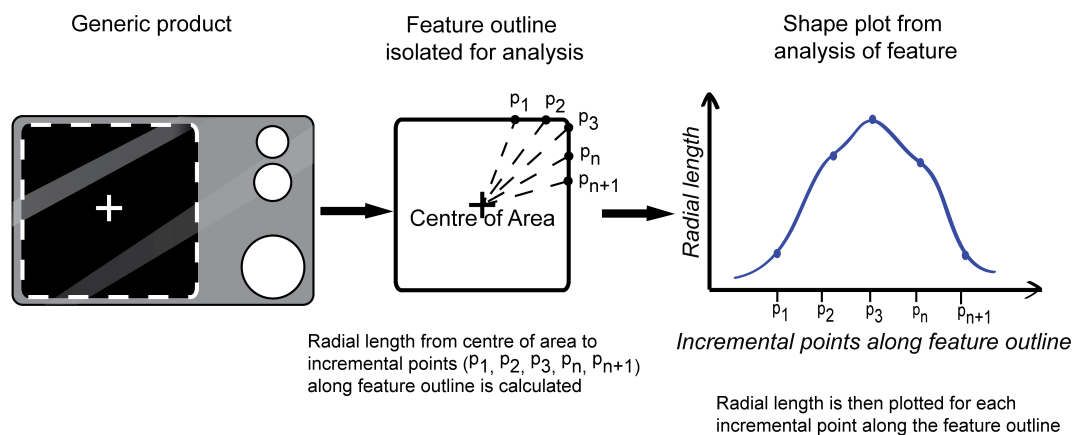


Figure 69 Illustrating shape analysis

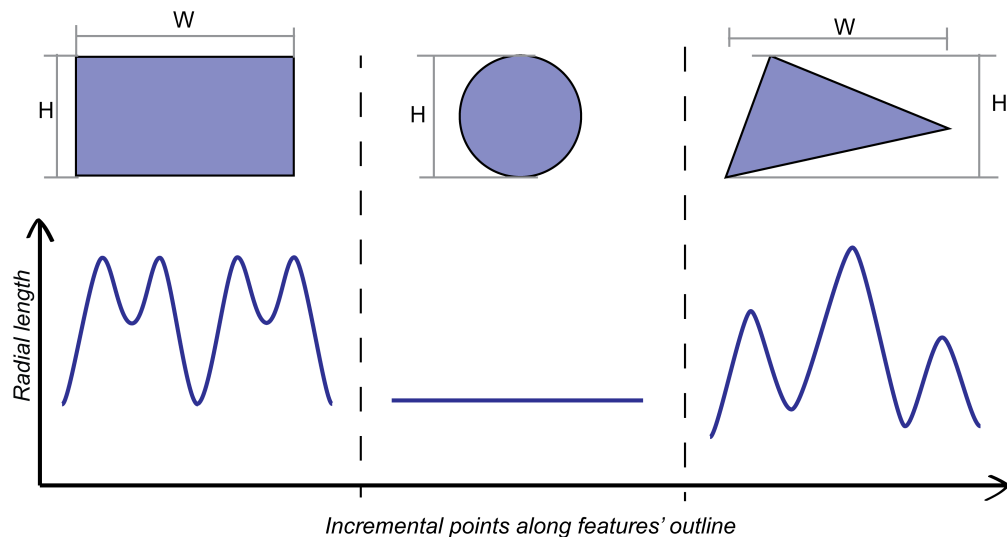


Figure 70 Examples of shape analysis data plotted for basic shapes

While the proportion analysis provides data relating to the relative basic dimensions of features and the orientation analysis to their relative position, the potential value in shape analysis is to visualise similarities and differences between the geometry of features. This is demonstrated in Figure 70 in that all shapes can be said to have the same height (H), the rectangle and the triangle both have the same width (W), and lie on the same axis. The key (and obvious) difference between the features is their shape. The data plots shown in the lower portion of Figure 70 demonstrate the manner in which it is possible to show differences in shape.

A number of steps have been taken in order to ensure that shape plots for features of all shapes and sizes can be compared directly. Firstly the same number of points (90) are distributed equidistantly along the feature outline/profile for all features. This ensures that the length of shape plots or 'wavelength' is the same for all features. Secondly incremental points are ordered such that the points can be considered equivalent for all types of feature shape. Simply put, incremental points all begin from the same or equivalent location an example could be where Y is a minimum and X = 0. The following section gives details of comparisons and aspects of appearance that can be represented.

8.2 Interpreting data from analyses

The previous section outlines three analyses that may be applied to products' appearance resulting in numerical measurements derived from feature geometry. This section discusses the interpretation of the resulting data with respect to appearance.

8.2.1 Interpreting shape analysis data with respect to feature geometry

In discussion of shape analysis data the resulting plots (termed shape plots) are discussed referencing terminology used in discussion of waves/signals and generic graphs. This is because resulting shape plots may be considered as finite phase of a sinusoidal wave. In this section characteristics of shape plots are defined along with the characteristics of features' appearance/geometry that they highlight.

Amplitude

Peak amplitude in the shape plots represents the maximum radial length from the centroid. Hence the peak amplitude in shape plots gives an indication of overall scale. Examples of the same shape scaled to different sizes are shown along with their shape plots in Figure 71

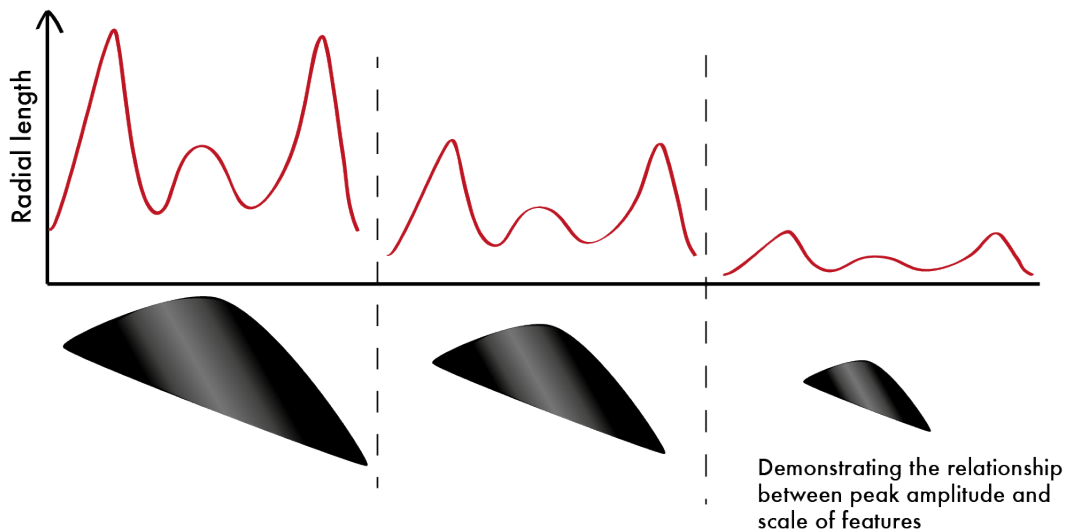


Figure 71 Relationship between peak amplitude and feature scale

Maxima and minima

The presence of maxima and minima in shape plots indicate the presence of corners in the shape investigated. The number of maxima indicates the number of corners

present. Figure 72 illustrates this showing three shapes with varying numbers of corners and their respective shape plots.

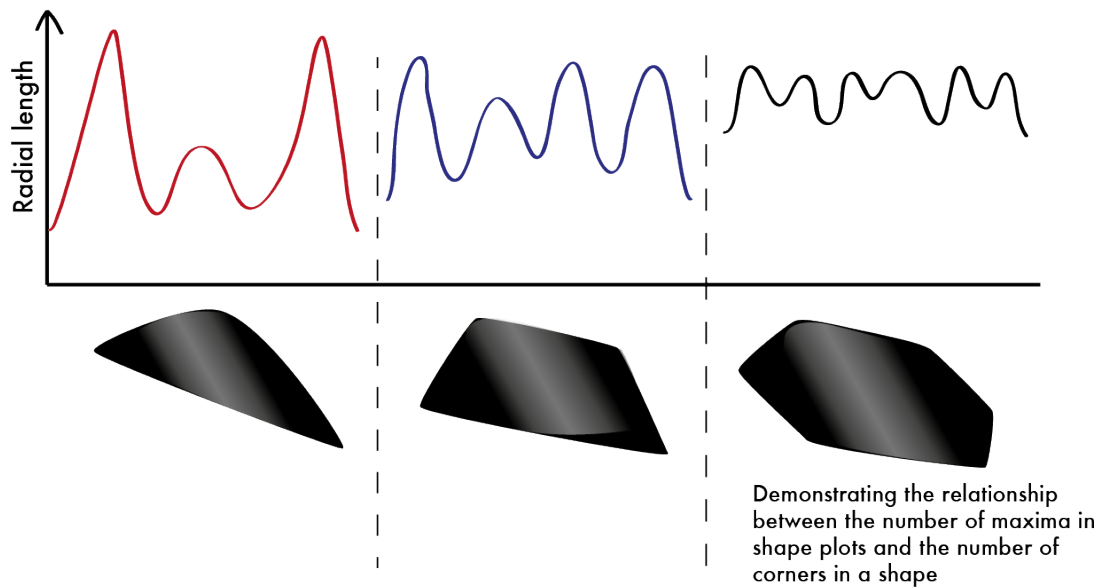


Figure 72 Relationship between maxima and number of corners

Magnitude of maxima relative to minima also referred to as peak-to-peak amplitude gives a broad assessment of the nature of corners with respect to edges. A large difference between maxima and minima indicates sharp corners compared to edges. It follows that a low magnitude in the difference between maxima and minima is indicative of sweeps. These relationships are indicated in Figure 73.

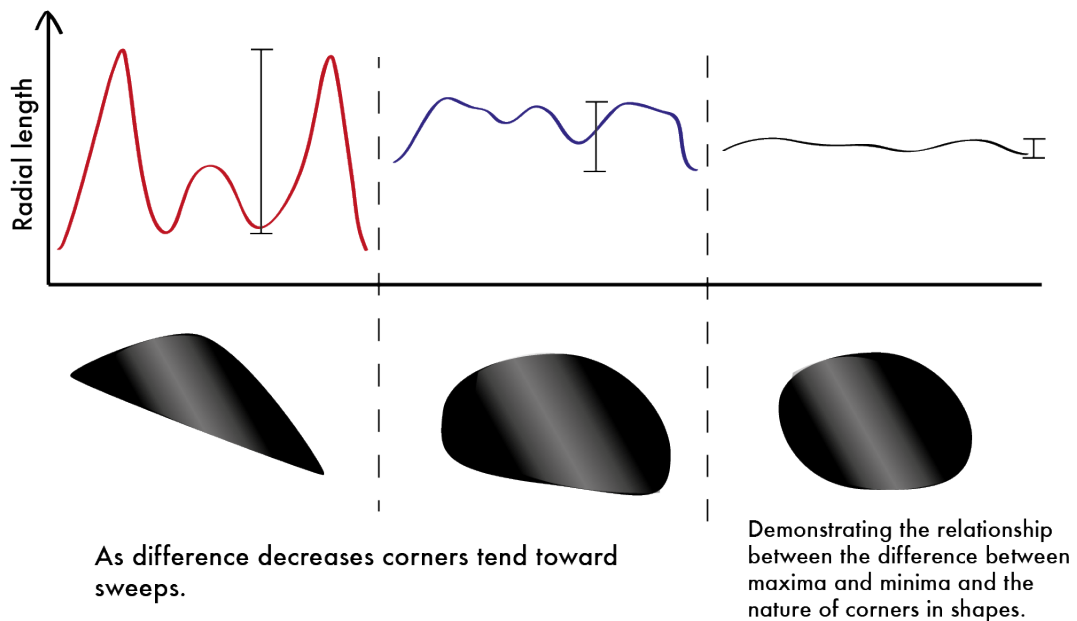


Figure 73 Relationship between difference in maxima and minima the nature of corners

Change in gradient

Change in gradient of shape plots gives an indication of the degree of curvature or sharpness of corners. The greater the change in gradient at a maxima or minima, the sharper the corner or the greater the curvature. Hence major changes in gradient of shape plots can be used to highlight corners as illustrated in Figure 74. Smaller fluctuations in gradient in shape plots are indicative of ‘kicks’ in feature profile.

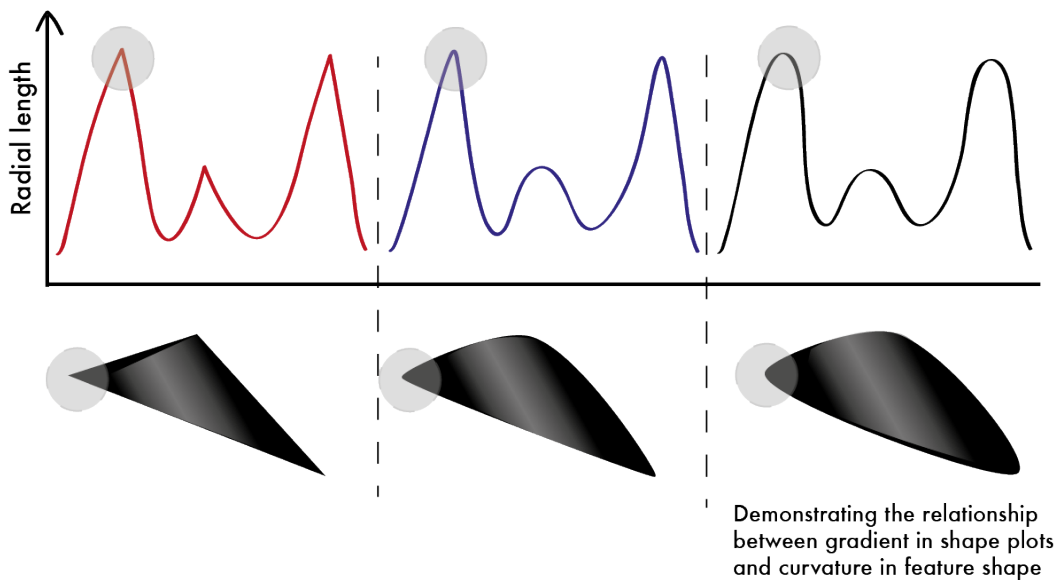


Figure 74 Relationship between gradient and curvature in corners

Skew

The skew of maxima in shape plots gives an indication of difference in the curvature of edges going into, or coming out of, corners. The greater the skew, the greater the difference in edge curvature.

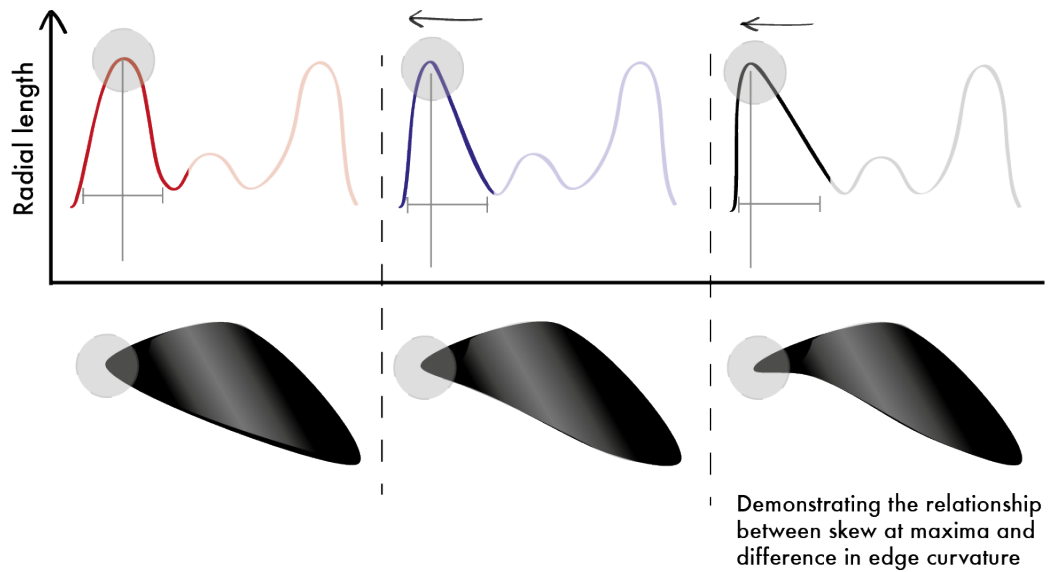


Figure 75 Relationship between skew in maxima and difference in edge curvature

With reference to Figure 75, it can be seen that curvatures of edges either side of the corner in question are roughly equal. This is embodied in shape plots by the maximum being equidistant in the X-axis between the adjacent minima. It can be seen that as the difference in curvature of edges either side of the highlighted corner increases, so the maximum becomes skewed toward one of the adjacent minima.

Symmetry

Both reflection and rotational symmetry can be observed from shape plots. Reflective symmetry of features is shown as reflections in waveforms of shape plots. Rotational symmetry is shown as repetitions of waveforms for every instance of symmetry. This is illustrated in Figure 76.

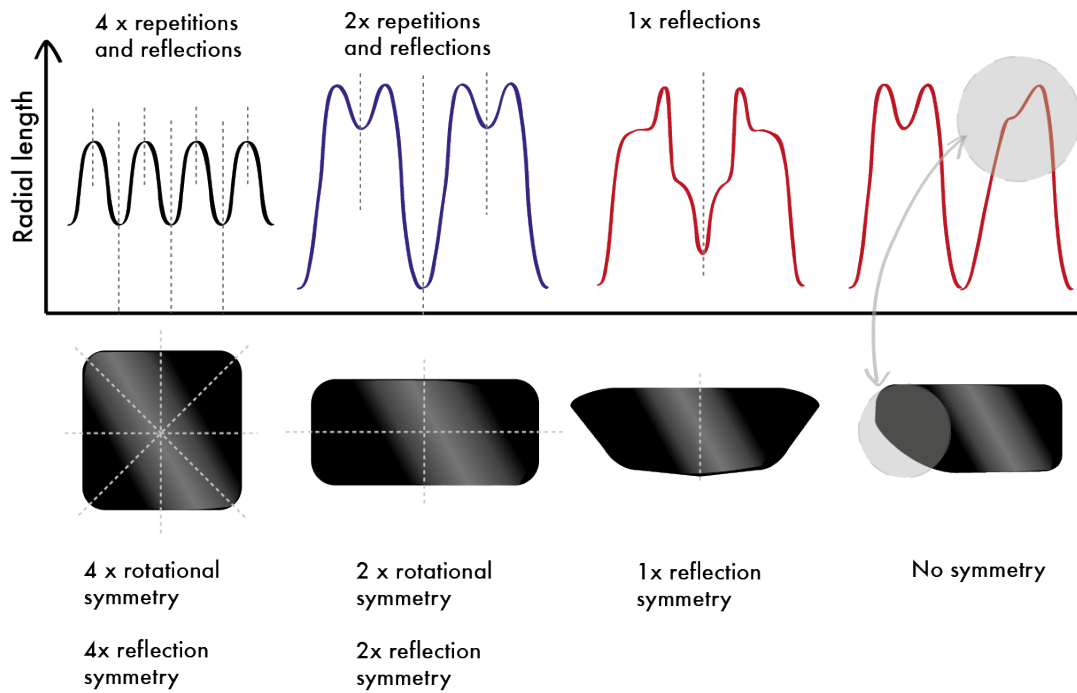


Figure 76 Demonstrating the relationship between reflection and rotational symmetry in features and the resulting shape plots

Rotation

Relative rotation of a feature can be observed through shape plots. The difference in shape plot as a consequence of rotating features is shown in Figure 77. It can be seen that as a feature is rotated the shape plot shifts phase relative to the original position. This has the effect of moving the starting point from which radial length is incrementally measured. It should be noted that, aside from the change in phase, the plot is unchanged.

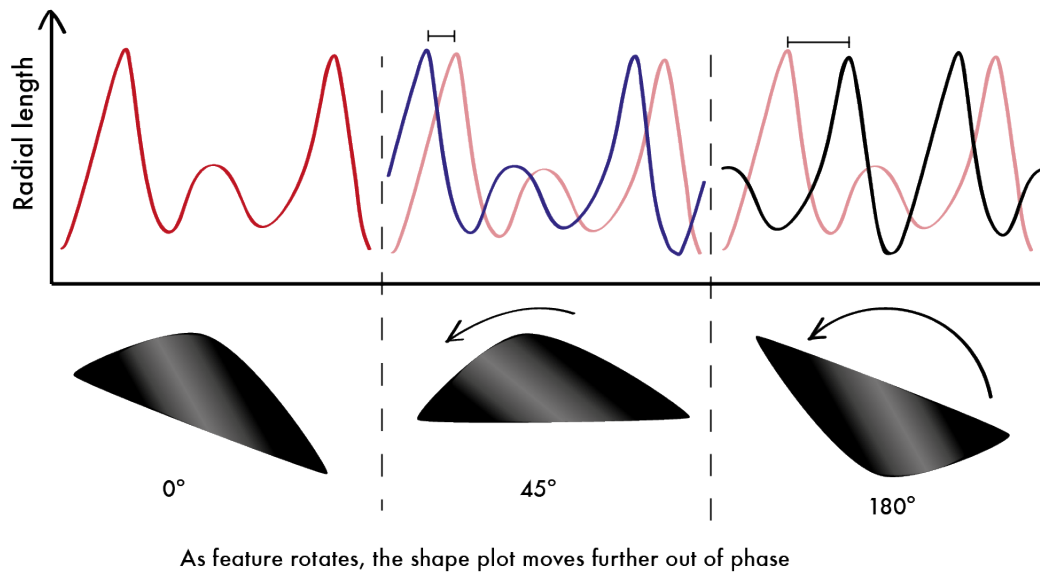


Figure 77 Illustrating the subsequent shape plots resulting from rotation of features

Following observation of relative rotation designers may choose to review the similarity in feature shape outside their context/positioning. This can be achieved by bringing shape plots into phase. This has the effect of rotating features such that a given point on the profile/contour align. Hence it is possible to consider difference in appearance as a result of the rotated feature as well as the similarity of the feature shape outside the context of its relative position and rotation.

8.2.2 Interpreting proportion and orientation analysis data with respect to feature geometry

Compared with data and plots from shape analysis, proportion analysis data is less abstract and thus more straightforward for interpretation. In proportion analysis, measures of area, perimeter, length and width of features are recorded as a proportion of the other features within the visual decomposition. This analysis requires very little interpretation as proportions are immediately identifiable and relatable to feature geometry. Patterns in proportions may then be reviewed by plotting values for specific proportions between features across a range of products as previously illustrated in Figure 67 and further addressed Figure 78.

As with proportion analysis data, orientation analysis data is relatively self-evident and requires little interpretation. Resulting orientation analysis data coordinates for a feature centroid and X and Y maxima and minima. These coordinates may then be

plotted globally for all features analysed. Given these coordinates, the variation in position can be analysed across a range of products as previously illustrated in Figure 68 and further addressed in Figure 79.

8.3 Assessing degree of similarity in appearance

This section builds upon the previously defined analyses in order to assess degree of similarity between product appearance. Similarity can be assessed in two forms, firstly direct comparison between two features can be made. Secondly similarity can be assessed with respect to a range of features. This could be a range of different features within one product or, for the purpose of this study, a range of equivalent features from a number of different products. The details of degree of similarity calculations are now discussed for each of the three types of analysis.

8.3.1 Degree of similarity in proportion analysis

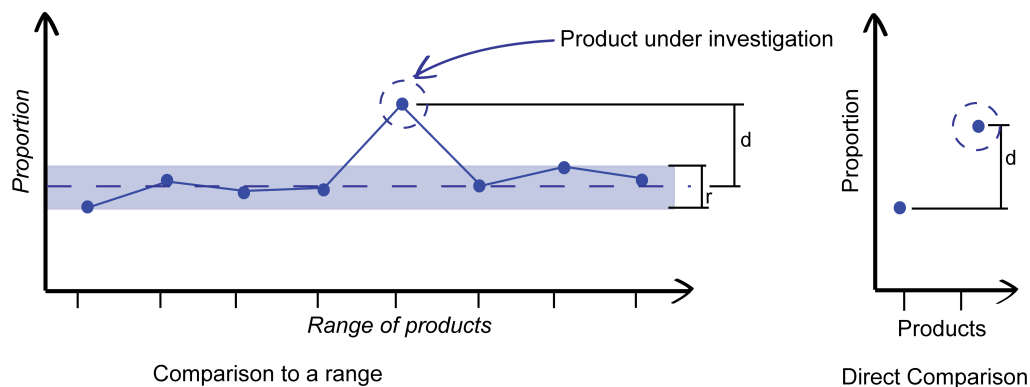


Figure 78 Illustration of degree of similarity calculation from proportion analysis

Direct comparisons of the degree of similarity can be assessed by calculating the difference (d) in any given proportion between the two products being compared.

For comparison with a group of products, degree of similarity is calculated as the difference (d) between the product under investigation and the mean value for proportion for the group of products (denoted by the dashed line in Figure 78).

The magnitude of the spread of values across the products investigated, termed the bounding range (r) of the products should also be considered to provide further context to assessment of degree of similarity between a product and a group of products. This is done by dividing the difference (d) by the magnitude of the bounding range (r) for the product range investigated. This in effect gives a comparison of the variation of a given proportion/point from the mean of a group against the variation seen across said group. Hence d/r gives a value for degree of similarity within the context of the variation across the range of products against which an individual product is to be assessed.

8.3.2 Degree of similarity in orientation analysis

The calculation of degree of similarity in orientation analysis is similar to that used for proportion analysis. The major difference is that it is done in two axes as relative position is being considered. Hence in direct comparisons the difference in position is calculated in both X and Y-axes as d_x and d_y . Similarly, with respect to a range of products, values for d_x and d_y are calculated as the difference in position to the respective X and Y range mean (shown as the dotted line through the bounding range in Figure 79). As with degree of similarity calculations for proportion, the bounding range is considered, however, this is done in two dimensions (r_x and r_y). Hence for this analysis a value for degree of similarity is derived from d_x/r_x and d_y/r_y . The derivation of the range and values to calculate degree of similarity are illustrated in Figure 79.

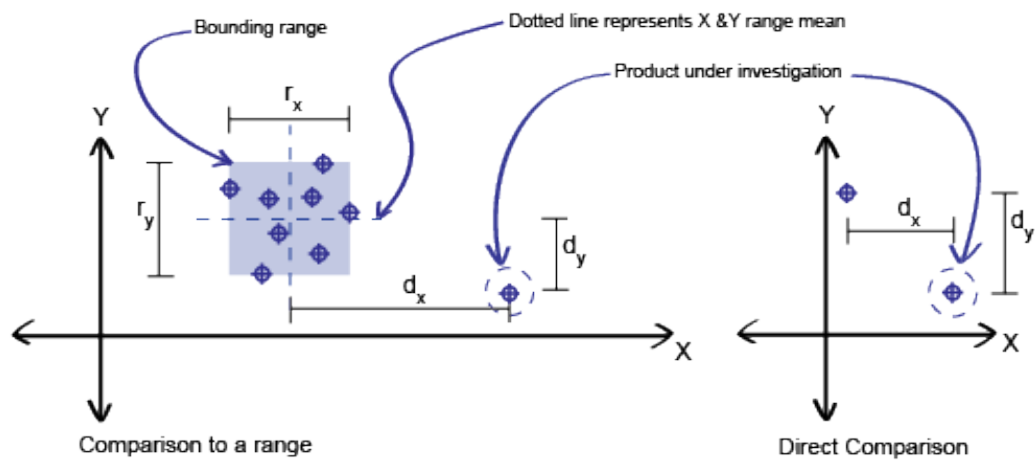


Figure 79 Illustration of degree of similarity calculation from orientation analysis

8.3.3 Degree of similarity in shape analysis

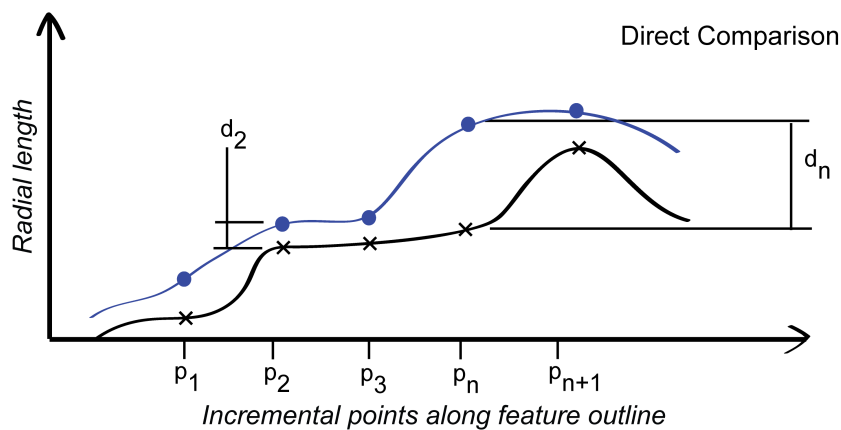


Figure 80 Illustration of degree of similarity calculation for direct comparisons from shape analysis

Degree of similarity calculations from shape analysis data also follow the same principle as those for proportion and orientation analysis. As discussed in 8.1.3, shape analysis plots the radial length from a given point on the feature outline to the feature centroid. Figure 80 illustrates the plot for this analysis with radial length on the Y-axis and given number of points evenly spaced along the shapes outline (labelled p_1, p_2, p_3, p_n and p_{n+1}) on the X-axis. Thus, in assessment of degree of similarity the difference between radial lengths (d_n) is calculated for each incremental point along a feature's outline. To obtain an overall measurement for degree of similarity in the direct comparison of two features, the mean value for d over all points along the outline is calculated.

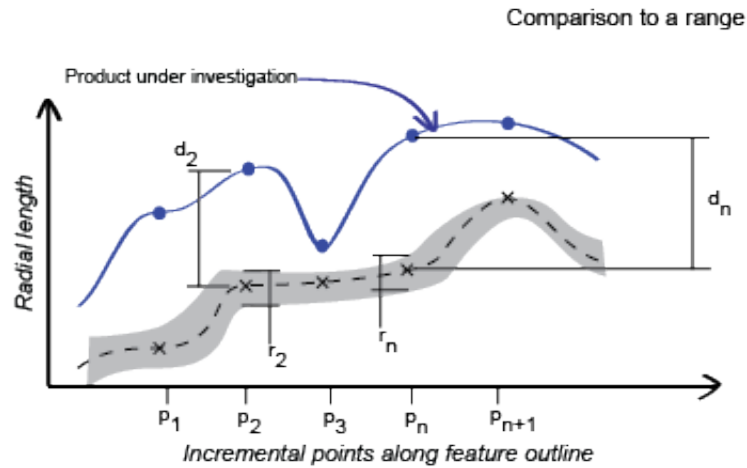


Figure 81 Illustration of degree of similarity calculation with respect to a range of products from shape analysis

As with other analyses, when calculating degree of similarity with respect to a group of products, a bounding range can be calculated using the mean value from the range of products. For shape analysis the mean value across the range is calculated at each incremental point along the outline. The difference (d_n) for the product under investigation is calculated against the range mean for each incremental point (denoted by the dotted line in Figure 81). Similar to the other analyses, a value for degree of similarity with respect to a group is calculated for each incremental point d_n / r_n . This may then be averaged to give an overall value for degree of similarity for shape.

8.3.4 Assumptions associated with degree of similarity calculations

In order for the degree of similarity calculations to provide insightful data on similarity a number of assumptions relating to the products examined must be made. Firstly a base or fundamental level of similarity is assumed.

Fundamental similarity

This fundamental similarity is defined as the presence of comparable features and observable similarity to the point where distinctiveness between products is based on nuances in feature shape, relative position and proportions between features. It is contended that these assumptions are reasonable for a number of reasons. Firstly the large number of products in competition with similar architecture, functionality and often parts, leads to a relatively high degree of similarity. With respect to products being designed, it is likely that numerous similar iterations on possible novel concepts

are presented and subsequently evaluated in the design process. Furthermore, inherent in the concept of visual references to brand is similarity or repetition in order that a feature can be familiar. Finally the proposed method is only intended for use in instances where there exists a relatively high degree of similarity across a group of products.

Size of bounding range

Within this assumption of base similarity there is some consideration as to the number of products included within the bounding range and the relationship with range size when calculating the degree of similarity. Figure 82 illustrates this consideration.

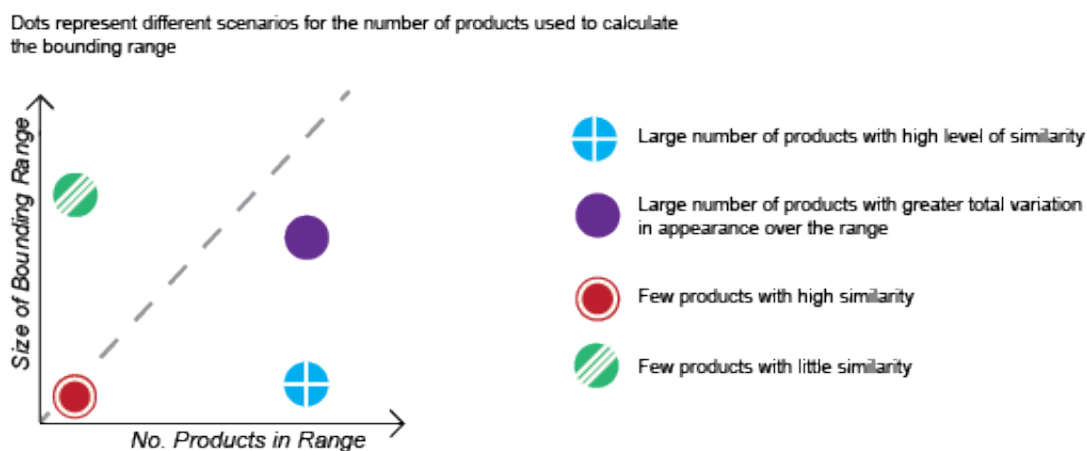


Figure 82 Illustrating the relationship between the size of bounding range and the number of products included

In the proposed calculation for degree of similarity, the size of the bounding range is dependent on the similarity in product appearance among the range of products used to create it.

If there is little similarity in products' appearance under analysis, the likelihood is that the bounding range calculated will be overly large and consequently products compared with respect to this range may be incorrectly considered as similar. Although a large bounding range is too large for degree of similarity calculations, it can still be used to quantitatively show the level of variation in appearance. A further consideration to the size of the bounding range is the number of previous generations of products included. It is possible that a range of products may show strong similarity between adjacent generations. However when constructing a bounding range based on a large number of generations, the total variation in appearance and consequent bounding range may also be too large. Hence it is assumed that the fundamental level

of similarity between products assessed is such that calculated bounding ranges are small enough to provide reliable values for degree of similarity.

Inclusion of products in the definition of bounding ranges

When comparing feature geometry of a product to a group of products there are two possible approaches for the definition of the product group. The first approach considers the product under comparison as being outside the group of products. The second approach considers the product under comparison as being included in the group of products.

Considering the use of the method to assess visual references to brand, it is assumed that the first approach is suitable when comparing a product to a product range produced by a competing manufacturer. It is thus also assumed that the second approach is suitable when comparing a product to other products made by the same manufacturer.

8.4 Overall method to measure similarity in product appearance

Having proposed three types of analysis and the calculation of degree of similarity for each, this section frames these steps within the method to measure similarity in product appearance. The analyses and subsequent calculations are used in conjunction with the visual decomposition process used to isolate and trace features, applied in chapters 6 and 7. The overall method is illustrated in Figure 83. It highlights the order in which the key processes occur along with inputs and outputs. It also gives details of the different steps/activities that are involved in each process. Comparing this proposed method (Figure 83) with that set out in the previous chapter (Figure 59) it is possible to see the way in which research has developed the method.

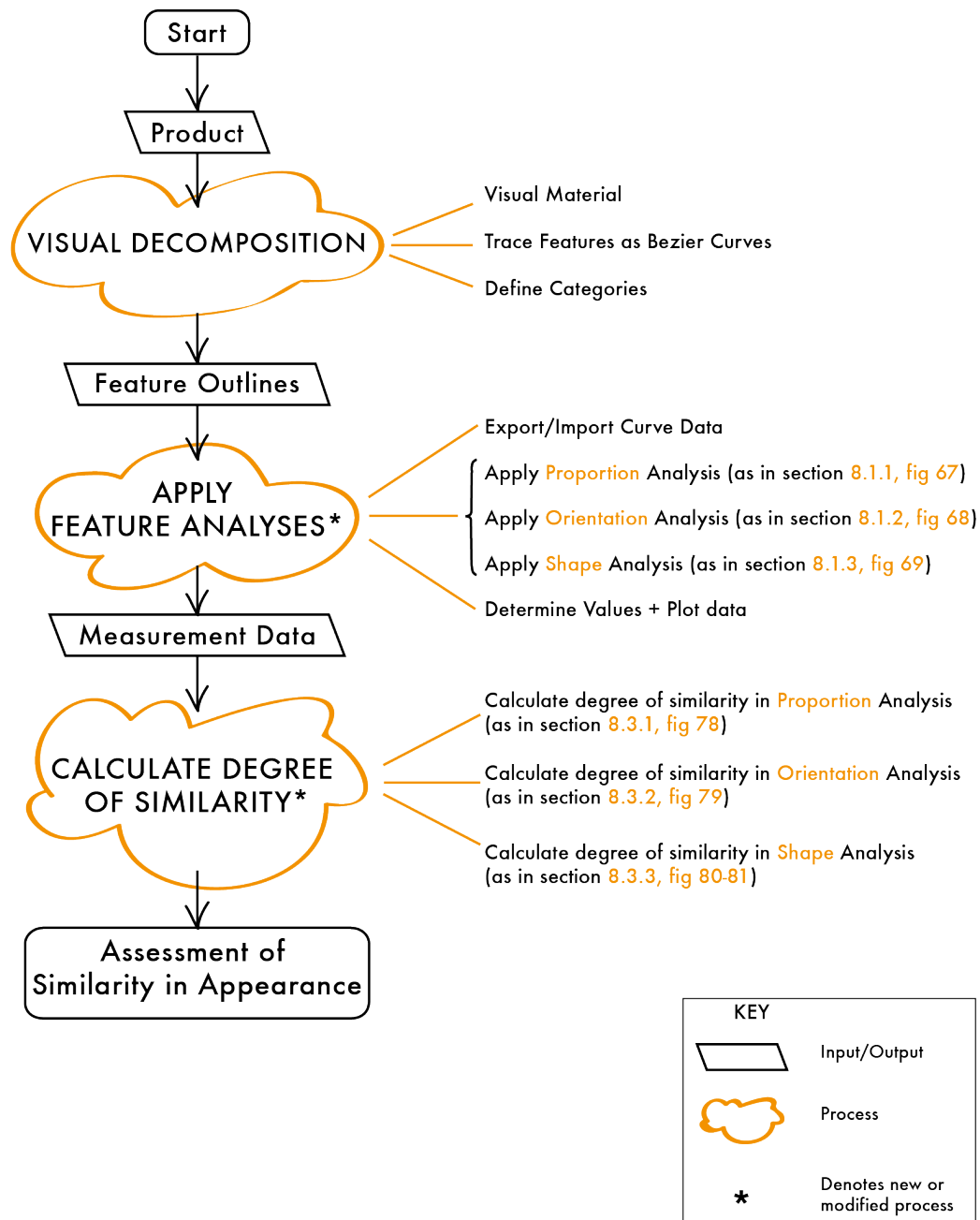


Figure 83 Proposed generic method to measure similarity in product appearance. NOTE the additional stages added to the initial generic method that was proposed for the scoping study (Figure 59)

8.5 Concluding remarks

The contribution of this chapter is the creation of a quantitative approach to measure similarity in product appearance through feature geometry (Figure 83). The first stage in the development of the approach was to create a set of analyses to measure different aspects of geometry. Analyses created measure proportional relationships between

features (proportion analysis), relative position of features (orientation analysis), and feature outline shape (shape analysis).

Following the development of analyses, the method to calculate the degree of similarity between features using measurement data from feature analyses is next proposed along with a discussions of the assumptions made regarding the similarity of products assessed. These elements are then combined with the visual decomposition technique from previous chapters to propose an overall method to measure similarities in products' appearance.

The following chapter details the application of the method to a range of smartphones, some of which are/have been the subject of litigation surrounding appearance. The application of the method used to test and validate the proposed approach.

9 CASE STUDY 1: TESTING PROPOSED METHOD TO MEASURE SIMILARITY IN PRODUCT APPEARANCE

This chapter presents the application of the method to measure similarity in product appearance in an industrial case to investigate its practical use and explore how it may be used to provide insights to support the styling process (objectives V and VI). The method is applied through a case study in which a limited range of smartphones is investigated using the analyses and calculations of degree of similarity to objectively review similarities in appearance.

The smartphones have been selected for a number of reasons. The first is that they are the subject of litigation concerning similarities in their appearance. Hence the application of the method in this case demonstrates one facet in which it can contribute insights to matters concerning similarity of appearance, and thus provide insights to support the styling process. Secondly this similarity is advantageous for the first case study as it rigorously tests the ability of the method to highlight very slight differences in appearance that are deemed similar.

The chapter begins by introducing the smartphones that form the subject matter of the case study followed by a summary of the application of the method to these products. Results from the analysis are presented and discussed and conclusions drawn on the similarities in feature geometry and the efficacy of the method to investigate similarity and provide objective insights on appearance.

9.1 Smartphones investigated

As introduced above smartphones are the subject matter used in to test the method. Smartphones produced by three companies Apple, Samsung and HTC were selected as

the subject of this case study. Details of the smartphones investigated are now discussed. Images of the smartphones are given in Figure 84.

Apple iPhone

The iPhone is a range of multimedia and Internet enabled smartphones produced by Apple Inc. (Beyer and McDermott, 2002). The first model was released in summer 2007 with subsequent improved models being released in summer 2008 (iPhone 3G), winter 2009 (iPhone 3GS) and winter 2010 (iPhone 4). Sales steadily increased during its presence on the market with over 100 million units sold worldwide to date (Apple, 2011).

Samsung Galaxy

In spring 2010 Samsung launched its rival smartphone the Galaxy S and subsequently the Galaxy S2 in summer 2010 (Yang, 2011). These products feature similar functionality and are of a similar size to the iPhone, the main difference being the use of an alternative operating system “Android” as opposed to the Apple operating system, iOS.

HTC Incredible

In early 2011 HTC launched the Incredible S smartphone (Engadget, 2011). Also running on the Android operating system and offering the same level of performance as the Samsung smartphones, the Incredible S can be considered as a direct competitor to the Apple and Samsung smartphones.

One of the motivations for applying the proposed method to this range of products is that some are the subject of litigation concerning similarities in appearance. In April 2011 Apple alleged Samsung had “slavishly copied” their smartphones and filed a lawsuit against Samsung on the grounds of infringing upon Apple’s intellectual property (Warman, 2011). These allegations include claims that Samsung’s products infringe on the grounds of ‘Trade Dress’. One aspect included under the umbrella of trade dress is product appearance or form (McElhinny et al., 2011). This aspect of the trade dress litigation is of particular interest to the research and the proposed method as this case highlights the importance of product appearance and branding.

In addition to gaining insights into the litigation surrounding the smartphones there are aspects of their appearance that make them ideal for this study. Firstly allegations

relating to copying implicitly mean that these products share a base level of similarity and are thus suitable for this method (see assumption section 8.3.4). Secondly their high level of similarity is ideal when testing the level of detail to which the method can provide useful insights on similarities in appearance. Finally it is contended that these smartphones also provide a suitable example of a mature mass-market products in that they have comparable functionality and balanced prices. Thus they are deemed to be suitable for gaining insights to the overall method presented in this thesis.

Apple iPhone 3G



Apple iPhone 4



Front

Side

Rear

HTC Incredible S



Apple iPhone 2G



Front

Side

Rear

Samsung Galaxy S



Samsung Galaxy S2



Front

Side

Rear

Figure 84 Images of smartphones used as the subject of the case study

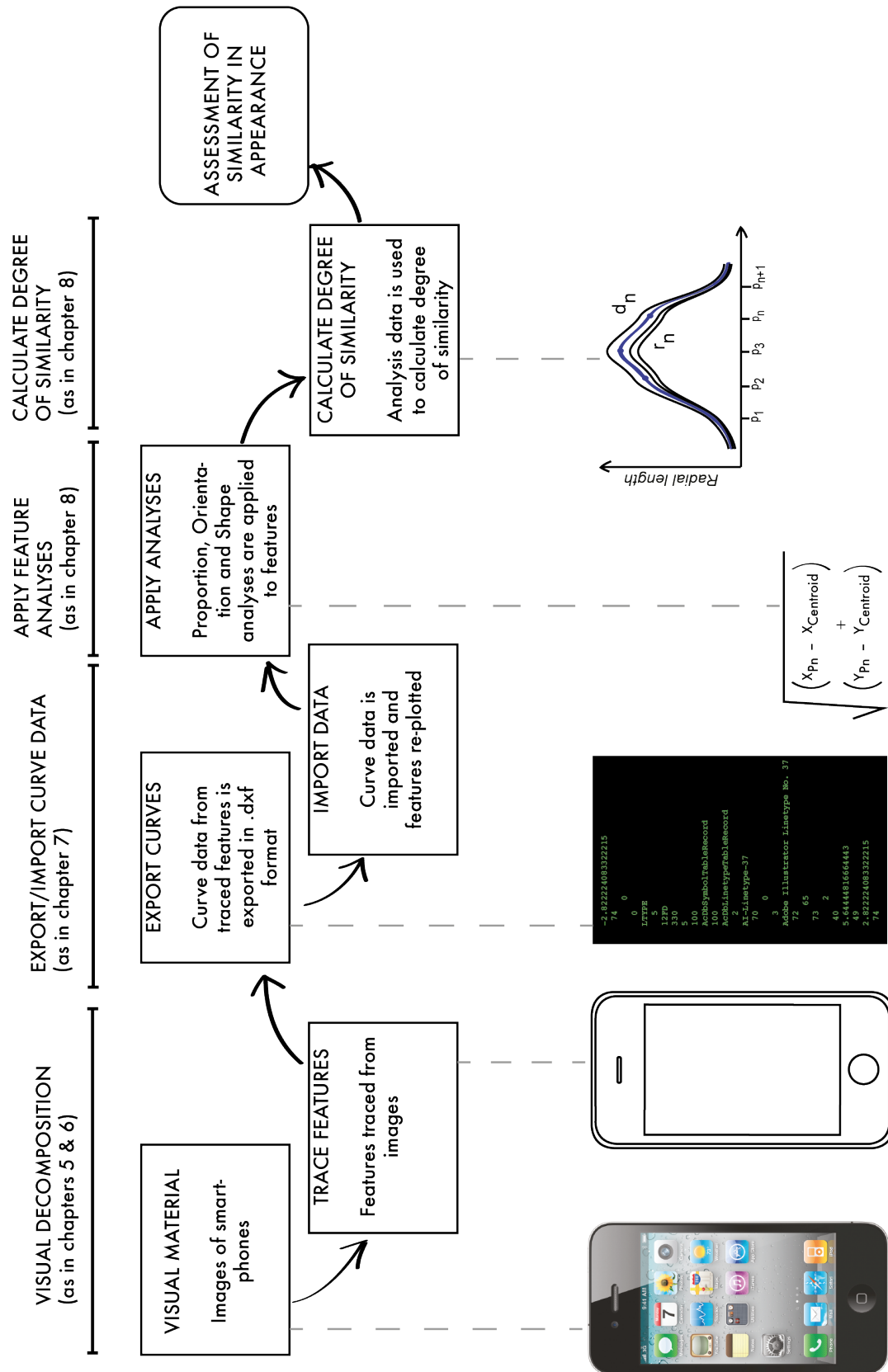


Figure 85 Steps followed to apply the generic method to measure similarity in product appearance presented in the previous chapter (Figure 83)

9.2 Applying the method to measure similarity in product appearance to smartphones

The application of the proposed method to measure similarity in appearance to this case is now detailed including the definition of features, application of analyses and degree of similarity calculations. The implementation of the method is illustrated in Figure 85. Details of how each stage is implemented for this case are now discussed.

9.2.1 Visually decomposing smartphones

The visual decomposition approach proposed in chapter 5 is adopted for the smartphones. Specifically, the images of front, side and rear elevations of the smartphones form the visual material. These form the basis for tracing features using chains of Bézier curves. Features traced are illustrated in Figure 86 using the Apple iPhone 4 as an example. All features, with the exception of one in the HTC are present across all phones. Thus fair comparisons may be made without the need for creating categories of features.

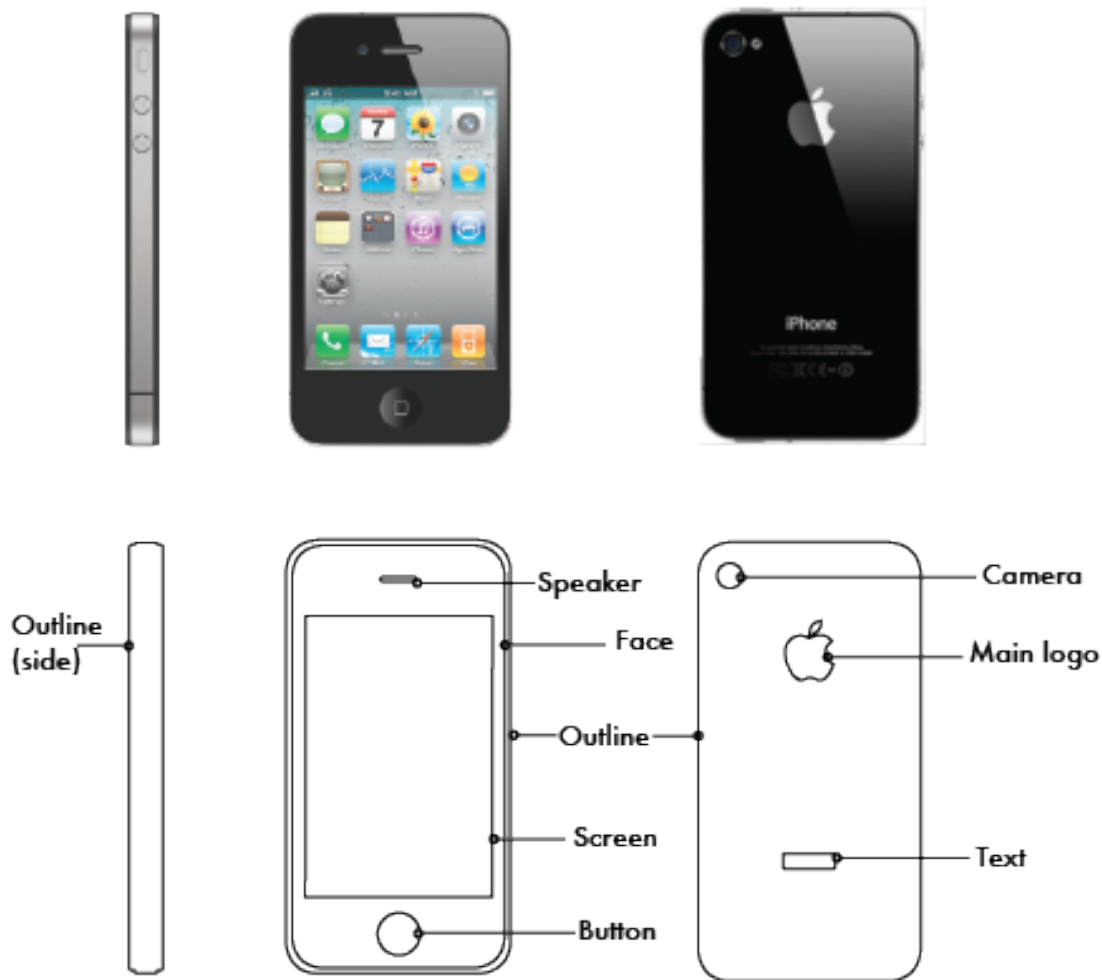


Figure 86 Demonstration of features isolated in visual decomposition using the Apple iPhone 4 as an example

9.2.2 Applying feature analyses

Due to the nature of features and presence of common features in different views, not all analyses (shape, orientation, proportion) could be applied in all views. The analyses applied to the different views are summarized in Table 8.

		ANALYSIS		
		Shape	Orientation	Proportion
ELEVATION	Front	✓	✓	✓
	Side	✓	✗	✗
	Rear	✗	✓	✓

Table 8 Applicability of analyses to different product views

The front view contains the most detail and also the greatest number of features that are common to all phones investigated. All analyses are applicable to this view. The side view only contains the outline of the smartphone. Consequently proportion and orientation measures were not applied as there is only one feature, thus it is not possible to define relative positions and proportions.

In the rear view four feature types are identified, a number are based on text. As the text was not traced, a bounding box through maximum and minimum X and Y values was used. As a consequence a shape measurement is not applied to these features. The outline in the rear view is the same as that in the front, thus although suitable for shape analysis there was no requirement to repeat the analysis. As a result, only the orientation of features was measured in the rear view.

9.2.3 Calculating degree of similarity for smartphones

For the purpose of investigating the claims made by Apple relating to ‘trade dress’ infringement, the degree of similarity calculations used compare features of the Samsung Galaxy S, S2 and HTC Incredible S smartphones individually to the three generations of Apple iPhones as a group. This approach is adopted in order to assess the degree of similarity between features of Samsung and HTC smartphones to what may be reasonably considered the Apple ‘aesthetic’/geometry

The calculations used follow those outlined in section 8.3 in the previous chapter. Thus the bounding range (r) is derived from the iPhones. The difference (d) from the Apple mean of the Samsung and HTC phones is then compared against the Apple bounding range. In accordance with the proposed method, d is compared with r using the equation d/r .

For the purpose of comparing individual smartphones to the iPhones as a group it is proposed that if $d/r \leq 1$ for a feature or part of a feature, then may be considered to be similar visually similar to the Apple iPhone ‘aesthetic’/geometry.

9.3 Results

Results from the application of the analyses are now presented. Results from the shape analysis are presented in 9.3.1, orientation analysis in 9.3.2 and proportion analysis in 9.3.3. The corresponding data plots from analyses are presented in Figure 87 - Figure 90.

9.3.1 Shape analysis of smartphones

When reviewing the shape plots in Figure 87 for Face, Outline, Screen and Speaker features, it can be seen to that they have similar plots that differ slightly in scale/magnitude reflecting similarity in the shape of these features. Key differences in plots are as a result of scale demonstrated by the maxima and minima in plots.

Notably from degree of similarity calculations comparing shape plots for the face feature, 71% and 94% of points for the Samsung Galaxy S and HTC respectively are within the Apple range. The screen and Outline features are less similar with between 24% and 9% of points lying within the Apple range.

A more substantial difference in shape may observed in the plot for the Button feature reflecting the different shape button used by Apple and Samsung, circular and rounded square respectively. It should be noted that there is no equivalent button feature on the HTC.

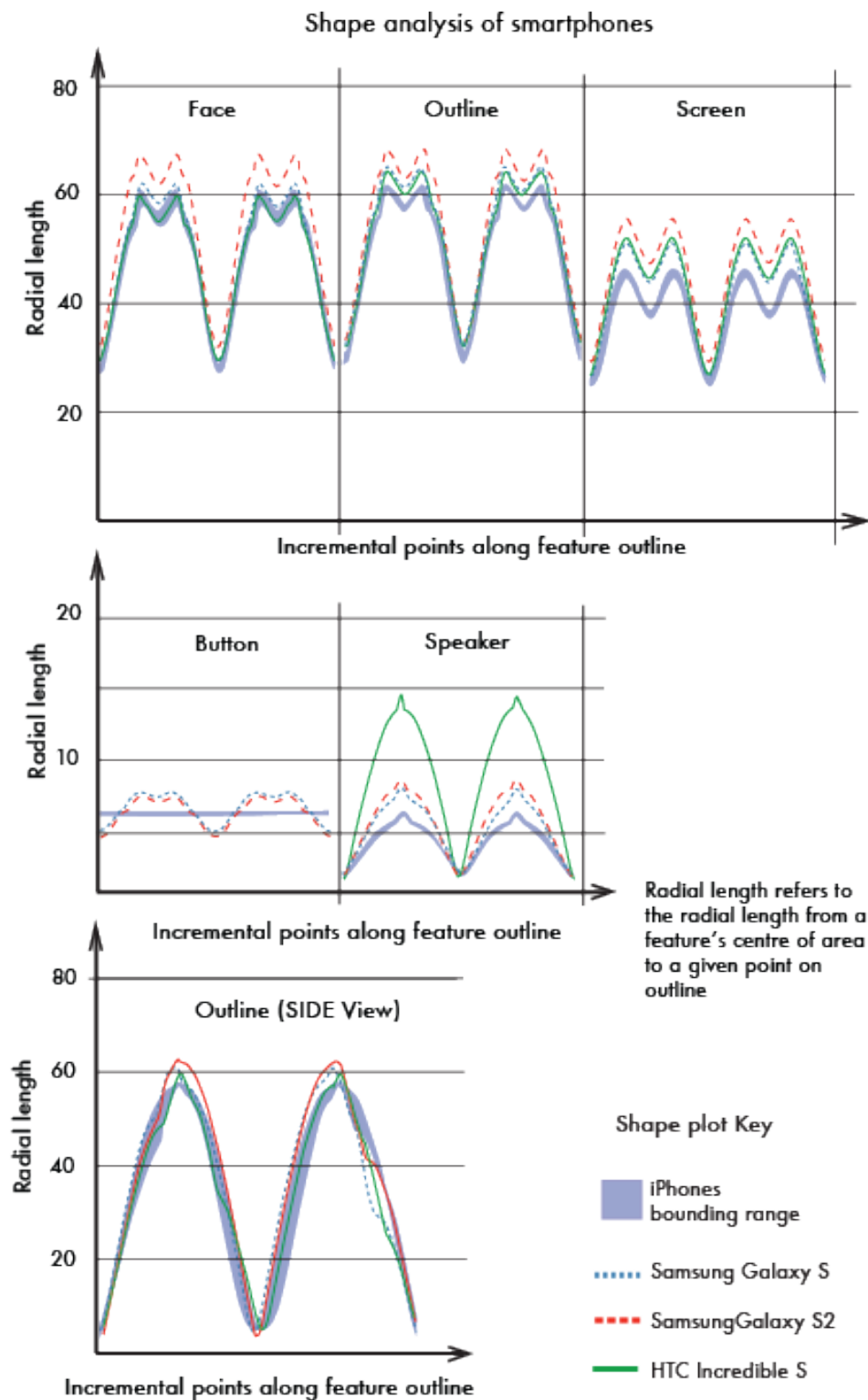


Figure 87 Results from application of shape analysis

In the side view (Figure 87) a greater difference in the geometry of all phones is observed including the internal variation across the Apple iPhone range. This can be seen in shape plots by the relative size of the apple bounding range and the variation in

shape plots for other phones. Much of this observable variation in the competition is due to the differing forms in the rear of phones (see Figure 84). The relative size of the Apple bounding range reflects the evolution in shape from a rounded side profile to a more angular form between the iPhone 3G and iPhone 4.

From degree of similarity calculations comparing side views, 66%, 71% and 76% of the shape plots for Samsung phones and the HTC phones respectively are within the Apple bounding range. The shape plots can be related back to the feature profile/contour to show that the majority of these differences occur at the ends and along the rear side of the outline.

9.3.2 Orientation analysis of smartphones

When reviewing the data on feature orientation in the front view (Figure 88 and Figure 89) it can be seen that phones appear to be highly similar. The location of centroids along the Y-axis shows that designs are generally symmetrical in the Y-axis while symmetry or balance in placement of speaker and button features may also be observed in the similar distances of the respective centroids from the origin.

Orientation analysis of smartphones: Feature centroids

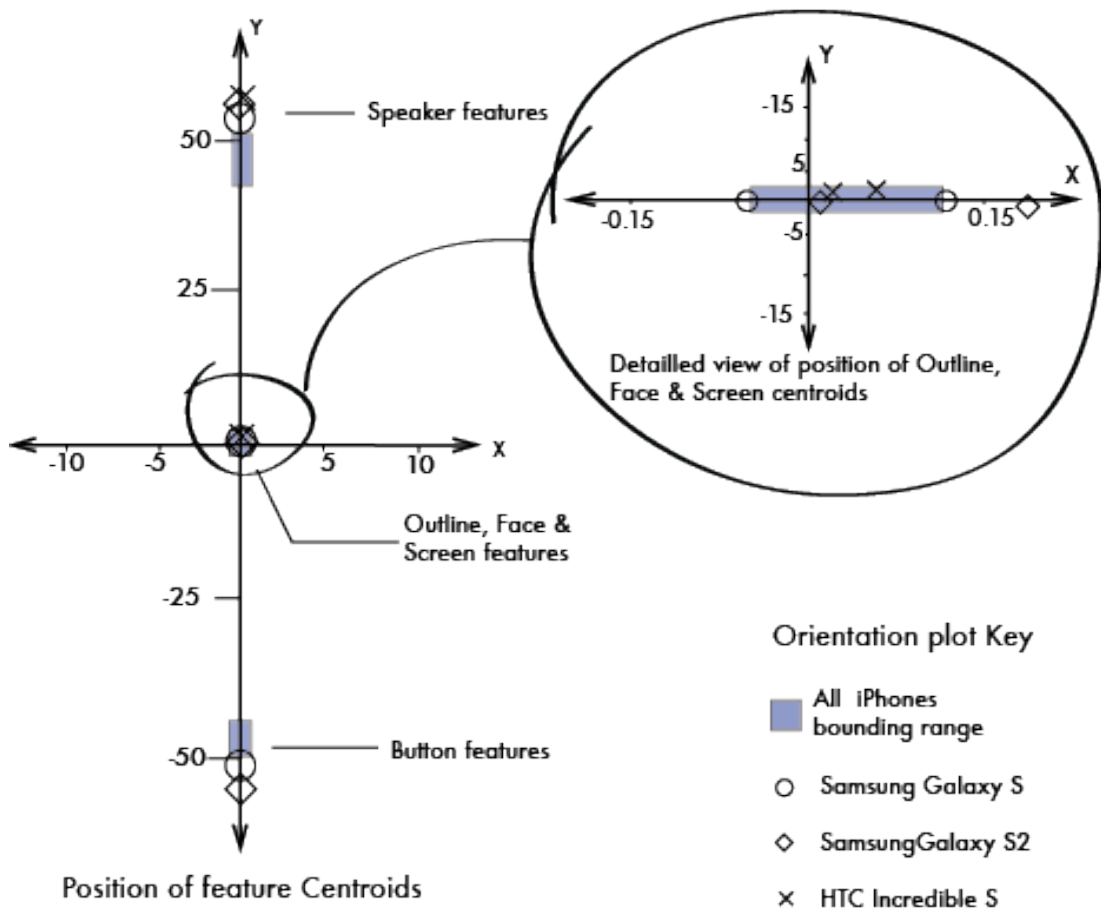


Figure 88 Results from application of orientation analysis analysis showing position of feature centroids

Making degree of similarity calculations shows that for the five features position coordinates (five X and five Y), 6 out of 10 for the Samsung S, 8 out of 10 for the Samsung S2 and 7 out of 10 for the HTC phones, were within the Apple bounding range. Position of maxima and minima further show the symmetrical nature of the smartphones and the similar shape characteristics highlighted in the shape analysis (Figure 89).

Orientation analysis of smartphones: Feature maxima & minima

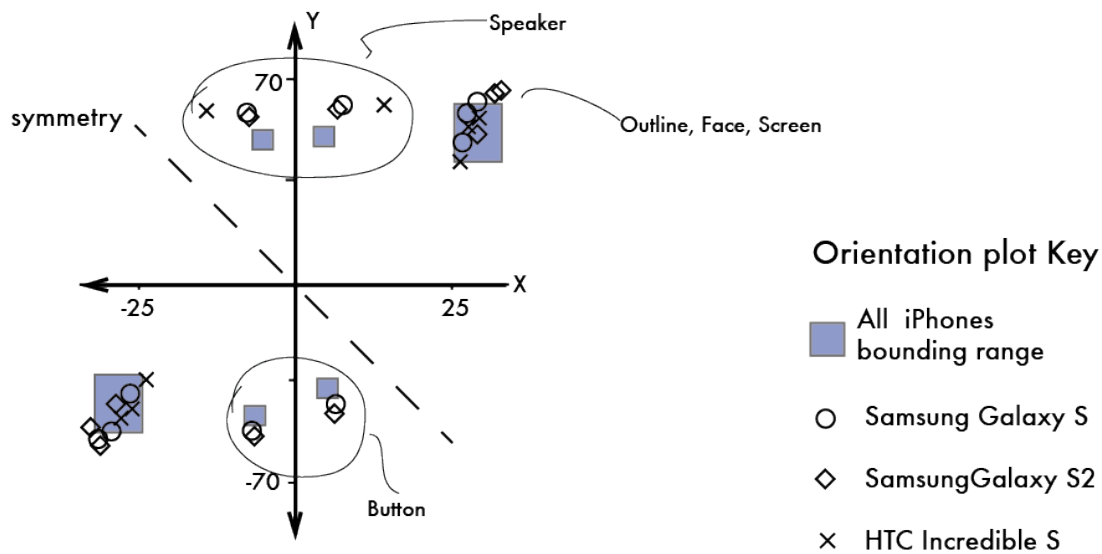


Figure 89 Results from application of orientation analysis showing position of maxima and minima

Although the position of the camera and logo features on the rear may be observed as being approximately in the same place, degree of similarity calculations show only two instances in which features are within the Apple bounding range. These are the ‘sub-text’ feature of the HTC and Samsung Galaxy S2.

9.3.3 Proportion analysis plots

When first examining proportion data shown in Figure 90, it can be seen that, as with other types of plot, there is a clear pattern in the relative proportions of different features. It can be seen that proportions in features follow a similar pattern across all phones. This reflects the high degree of similarity between smartphones’ appearance and constituent features. Degree of similarity calculations show that, of the 16 proportions compared across all features, 6/16 of the Samsung Galaxy S features are within the Apple bounding range and 5/16 features of the Samsung Galaxy S2 are within the Apple bounding range. The HTC is not within range in any of the instances. These instances are illustrated in Figure 90.

Of particular note is that the Face and Screen features expressed as a proportion of the outline consistently have similar relative proportions across all dimensions while Button and Speaker feature proportions differ more.

As with the orientation test for the rear view, few similarities were observed in the relative proportions of features. Degree of similarity calculations showed there are no instances in which the Samsung or HTC phones have proportions within the bounding range of Apple phones.

Proportion analysis of smartphones

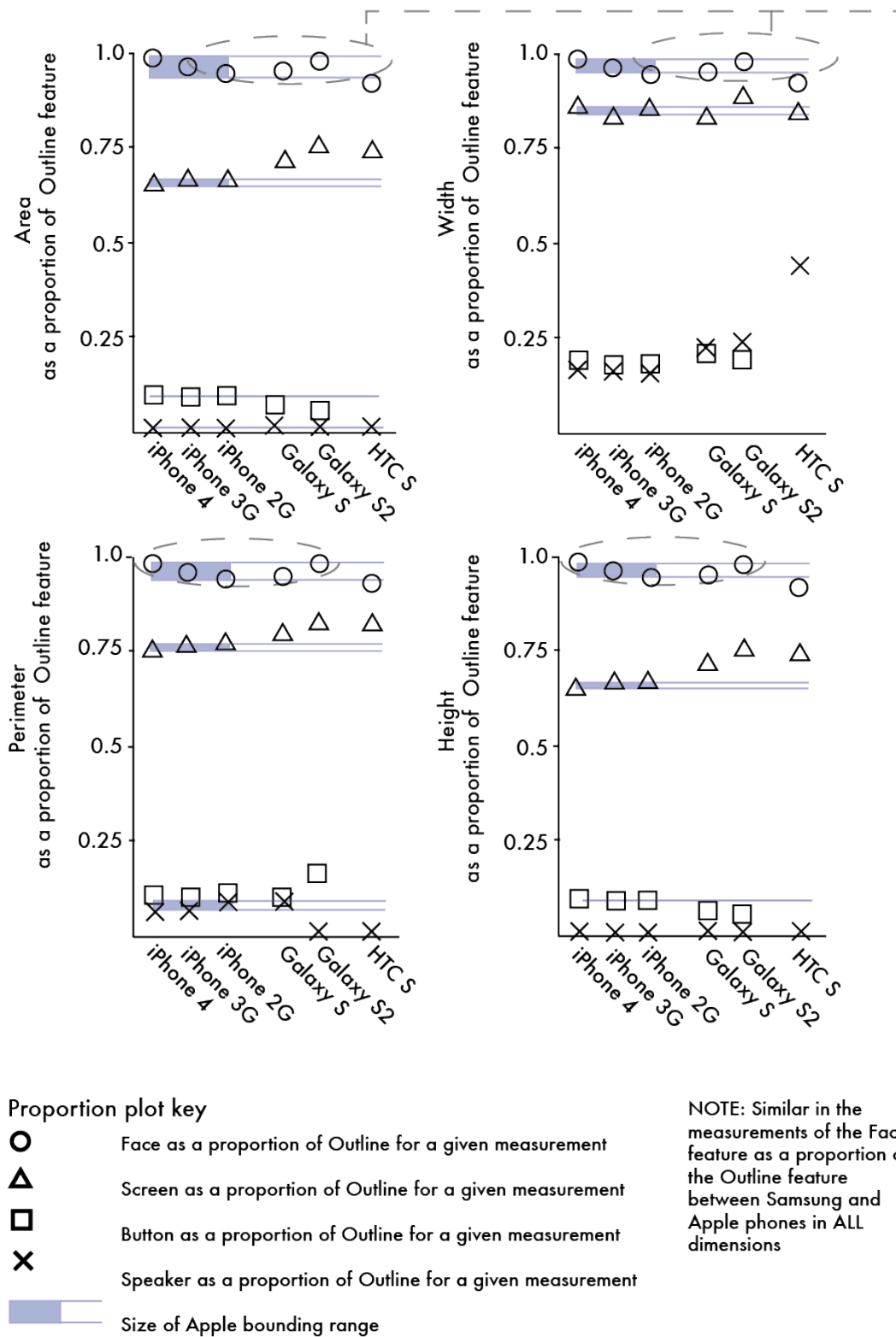


Figure 90 Results from application of proportion analysis to features in the front view

9.3.4 Systematic error associated with digitising product images

When reviewing orientation plots it is possible to get a measure of the systematic error in the tracing process for the features traced in this case study. It is logical that all features are designed to be symmetrical about their respective Y-axes and that the Y-axes of the features are coincident. Thus the deviation of centroids from the line of symmetry provides a measure for the systematic error in the tracing process. The average deviation from the centre line was found to be 0.13mm. Considering the smallest dimension of elements traced in the smartphones is 4mm the 0.13mm range gives a maximum margin of error of 3.25%. This error was deemed suitably small to give reliable results.

9.4 Discussion

This section discusses results from the perspective of the litigation concerning appearance while also considering the overall application of the method and its use to support designer's styling decisions. It also considers limitations of the method and makes proposals for its requirement.

9.4.1 Similarity in appearance of smartphones

This section discusses the use of analyses and degree of similarity calculations to investigate product appearance and similarities. Aspects of the smartphones' appearance are discussed with reference to resulting data plots from analyses and degree of similarity calculations.

The Shape analysis (section 9.3) reveals a number of similar characteristics of smartphone shape. The plots highlight the use of rectangular forms with rounded corners in all outline and face features. The simple rectangular form of the screen feature is also highlighted as being similar for all smartphones. The rounded rectangle form used in shape and outline features is distinguished from the simple rectangle of the screen in shape plots by slight deviations/nuances in the maxima.

The shape analysis also highlights the differences between the button feature used in the iPhones versus the more square button used by the Samsung smartphones. Shape

plots clearly distinguish these forms in the constant plot relating to the Apple iPhones compared with the more sinusoidal plot relating to the Samsungs (Figure 87).

The orientation analysis in Figure 88 shows symmetry in the designs and balance in the position of speaker and button features across all the smartphones. These attributes are highlighted in the relative position of feature centroids on the Y-axis of the outline feature. Balance is shown in the approximate equidistance of the button and speaker features from the X-axis of the outline feature.

The proportion analysis highlights similarities between Apple iPhones and Samsung phones in the proportions between the Face and Outline features. This is further confirmed when reviewing the front views of phones (Figure 84). Furthermore it can be seen that HTC phone is dissimilar in this respect, reflected by measurement data and review of images (Figure 84). These results illustrate that the main value of proportion analysis is to provide a broad framework of basic feature dimensions and the relation of these with respect to other features, an important part of the overall gestalt.

Although the differences revealed by the three dimensions of analysis are easily identified by visual inspection, the numerical quantification enables the determination of a measure of degree of similarity. Additionally it is possible to consider similarities in terms of a range of products rather than simply making direct comparisons. It should be noted that in the case study the product and their features are similar and arguable represent one of the most similar product groups.

9.4.2 Limitations and proposals for improvement

As discussed in 5.2.1 there are some limitations associated with the use of images as the base material for visual decomposition and subsequent application of analyses. Considering the possibility of using 3D surface data over images as a base material, it is contended that the analyses proposed can be easily extended to consider three dimensions. This would be achieved by considering a third dimension in proportion analysis, thus investigating volume and depth. For orientation analysis, depth (the Z-axis) is easily added. In shape analysis, a ‘cloud’ of incremental points on a surface can be assessed against a feature’s centre of surface area of the shape. Subsequent shape plots can then be represented and compared as surface plots.

9.4.3 Further use of the method for other products

In consideration of the further use of the proposed method with other products, namely vehicles a number of observations are made. Firstly the smartphones reviewed are very much alike in appearance to the point of legal action being taken. Secondly it is observed that the geometry that makes up the smartphones is relatively simplistic. All of the forms are based from simple rectangles with radiused corners.

As discussed in 9.1 this is advantageous in testing the method as it validates the efficacy in highlighting subtle differences. However there is also a need to test/apply the method to products with a lower base level of similarity and that incorporate more complex forms to better test efficacy and investigate the use of the method to best support designers.

Further to the above observations, it is noted that there are only a limited number of smartphones assessed (six) and their context is somewhat particular. This is to say that the comparison of appearance for litigation is only a small aspect of styling and not a significant part of the design process. Hence the use of the method should also be considered in line with the different reasons/strategies that motivate styling and inform decisions relating to appearance.

9.5 Concluding remarks

This chapter seeks to test and validate the proposed method to measure similarity in product appearance (chapter 8) and in doing so begin to explore its use to provide insights to support the styling process. To achieve this, the method proposed in 8 was applied to a limited set of smartphones, currently the subject of litigation concerning their similarity.

Results from the application of the method are used to make a number of conclusions on the nature of similarity in the smartphones appearance. Specific elements of similarity are shown in face and outline features and in the orientation of features in the front view of the smartphones. Investigation of the side view outline profile highlights the areas in which the smartphones are more distinct.

In terms of the litigation between Apple and Samsung, it is not possible to validate or dismiss claims of copying by Apple. This is partly because there is a need to consider other aspects of appearance such as colour and material, and partly because such judgements go further than consideration of similarity into the spheres of the intellectual property law. The resulting data does however provide explicit details of similarities and the degree to which they are similar, providing valuable and objective insights in the eventual decision relating to these claims. Furthermore, in providing such data, one example of the use of the method to provide insights to support the styling process is demonstrated.

While the results from this chapter both demonstrate the use of the method and aspects of its potential provide insights to support the styling process, the contribution is very specific to the case investigated. In other words, a limited set of products that are particularly similar. Thus in order to fully meet objectives V and VI there is a need to further investigate and demonstrate how the method can provide insights to support the styling process across the broader range of design strategies and scenarios with respect to appearance discussed in section 4.3. In particular there is a need to expand the method such that these factors are actively considered within the method.

10 A METHOD TO MEASURE AND COMPARE PRODUCT APPEARANCE

This chapter primarily addresses objective V in investigating the way in which the proposed method can provide insights to support the styling process. This is done by exploring the context of products to provide guidelines for how measurements of similarity in appearance may be interpreted. This results in the addition of two key stages to the method proposed in chapter 9 (Figure 85) in order to propose an overall generic method to measure and compare appearance.

The chapter begins by exploring the contextualisation in which appearance is evaluated. A generic ‘product space’ is developed to illustrate the different products in different contexts. The needs/requirements of designers when evaluating appearance are then extracted with reference to literature (4.3) and interviews (3.3). These are then presented in the context of the product space. Strategies to answer these requirements are next derived from degree of similarity calculations. Finally the further considerations are addressed and guidelines for the interpretation of degree of similarity are presented along with the overall method. This includes visual decomposition, the application of analyses, degree of similarity calculation along with the further contextualization addressed in the beginning of the chapter.

10.1 Product space

The generic context into which newly designed products will be launched is now termed the ‘product space’. The product space developed is similar to the model for product demarcation and distinction proposed by Person et. al. (2008) in section 4.3, however it introduces a further dimension in the distinction between competing brands. A product may fit within the following space which is defined by the dimensions, product range, product history and competing brands. The space is illustrated in Figure 91 also including an example using the automotive industry.

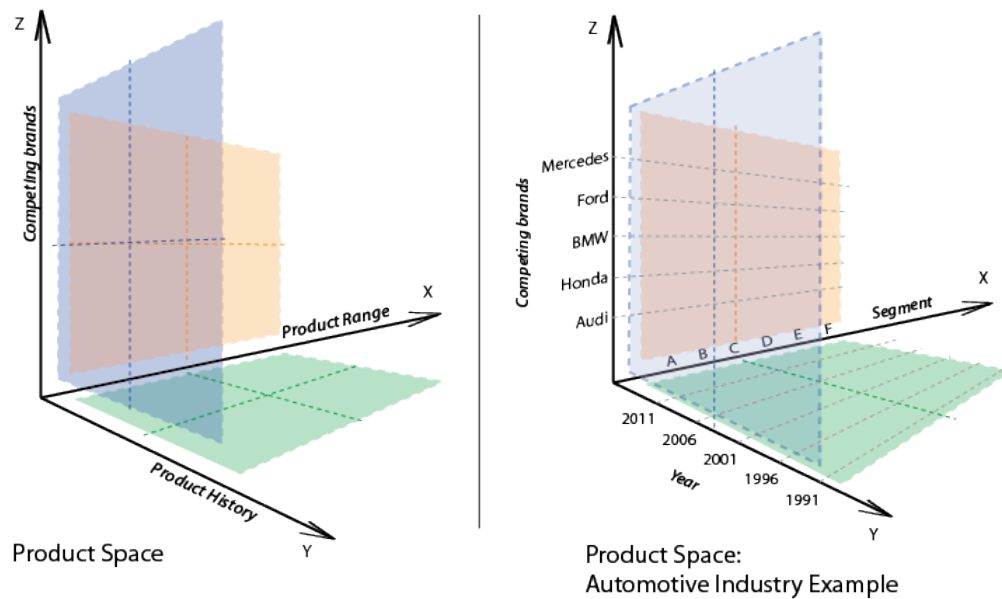


Figure 91 Illustration of the product space along with an example product space for the auto motive industry

The details of what is represented by each of the dimensions is now discussed.

- X-axis: Product range

This dimension represents the range of products produced by a given brand at a given time. In the automotive industry example, this axis is divided into the different ‘segment’ cars that a company may produce within its portfolio such as city car, mid-size, family car or 4x4.

- Y-axis: Product history

This dimension introduces a time element to the product space. It allows for the consideration of previous (and future) versions of a product or product range. In the automotive industry example this axis represents years in which different models were introduced/available.

- Z-axis: Competing brands

This dimension outlines the other brands that may be in competition in the market for a given product or product range. In the automotive industry example the different brands that could be said to be in competition are included on this axis.

The requirements of designers shown in interviews in 3.3 and from the literature (4.3) are now discussed with reference to the product space.

10.1.1 Comparisons across a brand's current range

When evaluating products in the current range produced by a brand, one of the most important considerations concerns consistency and the evaluation of what is consistent or inconsistent and why.

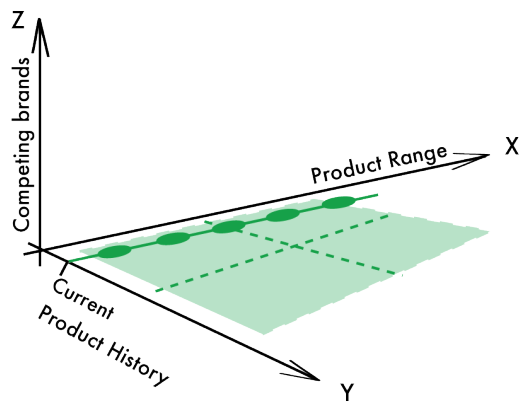
The value in such comparisons to designers is in the ability to assess other products in a product range for trends and what may be considered as visual references to brand. Hence an increased understanding of the range in which a product must fit/be identified is achieved. Thus for comparisons of the current range, emphasis is placed on understanding consistency and congruence within the current brand range. Comparison of current range products is illustrated in Figure 92a in terms of the product space.

10.1.2 Comparisons to previous versions of a product

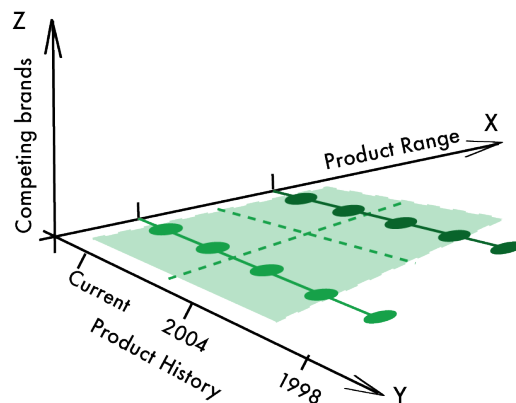
As with consideration of the current range, consistency in appearance is also considered in comparison of previous products made by a brand to gain an understanding of visual references to brand used repeatedly over generations of products. Furthermore the evolution of appearance can be considered to understand the evolution of design language through different generations of products (Figure 92b).

It is possible to extend comparison against previous product to compare two groups (also illustrated in Figure 92b). In this case the comparison of groups of previous versions of particular products may be compared. In doing so the evolutionary trends in the appearance of one product may also be compared with the trends seen in another product.

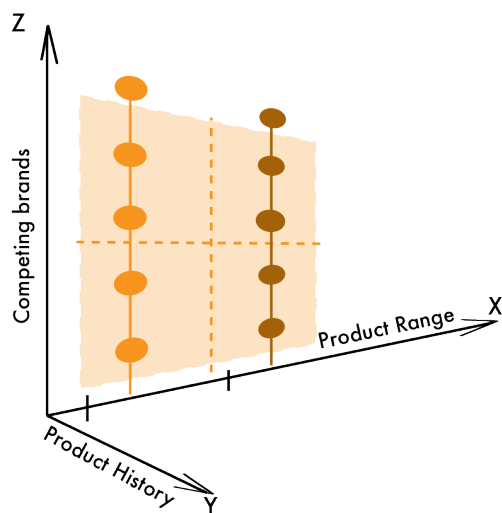
Identifying similarities and differences in trends can be used to forecast or inform the further evolution of products' appearance while also helping designers to reinforce ideas of what constitutes visual references to brand.



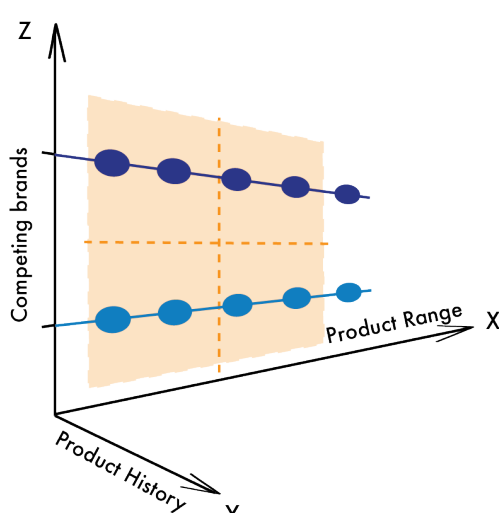
a) Comparison across a brand's current product range



b) Comparison against previous versions of a product or group of products for a given brand



c) Comparison with direct competition from other brands for given product model



d) Comparison of current product range with that of a competing brand

Figure 92 Illustrating possible comparisons in the context of the product space

10.1.3 Comparing products with competition

When considering competing products the major consideration is in how a product or product range is different or distinct from other products. For competing products it possible to make two types of comparison illustrated in Figure 92c and Figure 92d.

Figure 92c illustrates the comparison of a particular product with all other products in direct competition from other brands. This may done for multiple products. Such comparisons may be useful in highlighting aspects of appearance that make a particular model distinctive from its competition. It can also highlight aspects of appearance that may be considered archetypal for competing models. Thus such

analysis can be considered when addressing novel designs to ensure and promote distinctiveness.

Figure 92d illustrates comparison of complete ranges/portfolios of competing brands. The value of this type of comparison is in highlighting distinctiveness seen across complete brand ranges. This in turn can give further insights on strategic use of certain features throughout a brand's portfolio that make the brand's products visually distinct from competitors.

10.2 Using degree of similarity to provide insights to support the styling process

This section relates the types of comparisons contended to provide insights to support the styling process from the previous section (10.1) to the generic method proposed in section 8.4 (Figure 83). Specifically comparisons made to investigate consistency, evolutionary trends and distinctiveness are now derived from degree of similarity calculations proposed in section 8.3. These are then illustrated through examples in which hypothetical measurement data from products is plotted and compared and related to the product space. The terminology and illustrations used in this section are derived from the method and accompanying illustrations presented in 8.3, Figures 78 – 81.i.e. difference (d), and range (r). It is recommended that the reader return to these figures for reference during this section.

10.2.1 Investigating consistency in appearance

Consistency in feature geometry is derived from the variance in measures of a given feature within a group. In terms of the degree of similarity calculations, consistency is assessed by investigating difference from the mean (d) across a group of products. Figure 93a illustrates two examples of extremes of consistency and relative inconsistency with corresponding low and high variance.

It should be noted that, for comparison of features in shape analysis and proportion analysis, the coefficient of variation is used. This is done in order that values for variation can be compared uninfluenced by features' scale. The coefficient of variance is not required in the orientation analysis as it addresses coordinates for position,

values for which are independent of scale. For the purposes of illustration, the charts shown in Figure 93a are of the same scale. Also of note is that points for a given analysis are represented joined up in charts. This is done in order to visualise and help identify trends and consistency across a range of products.

10.2.2 Investigating evolutionary trends in appearance

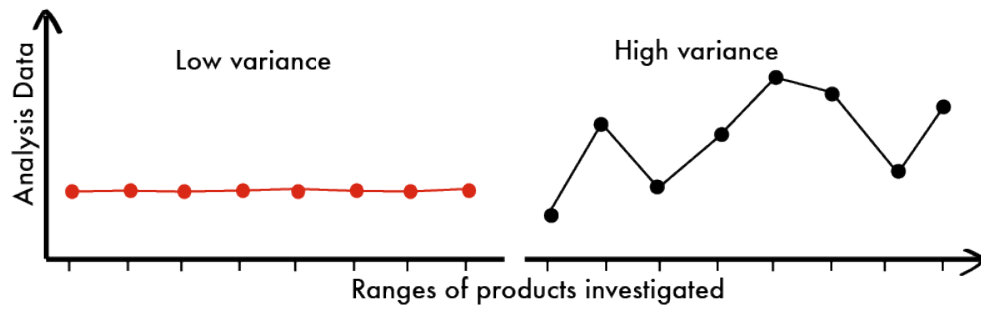
Evolutionary trends are exhibited in terms of degree of similarity as changes in geometry over a succession of products. Figure 93b illustrates two examples of evolutionary trends. The first illustrates a steady change in a given aspect of geometry over a range of products, the second illustrates a case in which a sudden step change occurs within a range of products.

In terms of degree of similarity, incremental change can be highlighted/observed as incremental differences (d) between adjacent products. Step changes are observed as a relatively large difference (d) between two consistent (low variance) groups of products.

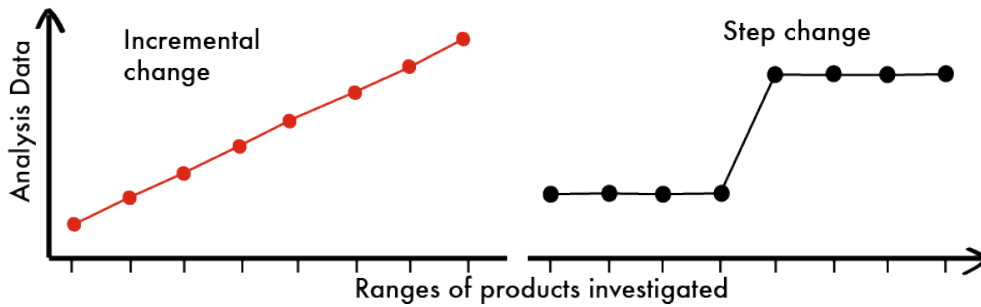
In the analyses of these scenarios, calculation of variance, or coefficient of variation indicates little consistency. In the case of incremental change, adjacent products are in fact similar, however considering all products, the variance calculated is relatively large. In the step change scenario, variance is low either side of the step, however as a whole variance is also calculated as relatively large.

The key value in investigating evolutionary changes in appearance is in the ability to represent and visualize evolution in appearance and features and thus be able to reason on strategy and future decisions by referring back to evolutionary trends. As with interpretations of consistency and distinctiveness, numerical analyses derived from degree of similarity calculations are not expected to be used in isolation.

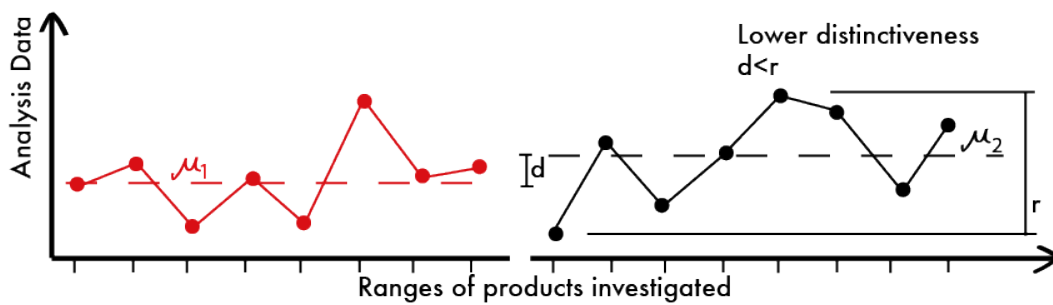
The expectation is to examine trends and inform decisions and provide direction and inspiration to designers. For example, in cases of steady change, a forecast for future characteristics can be created. Conversely step changes can be explored or forecasted for future designs. Finally trends that may be driven by external constraints may also be highlighted and reasoned upon. For example, trends constrained by technical performance or technology used can be examined.



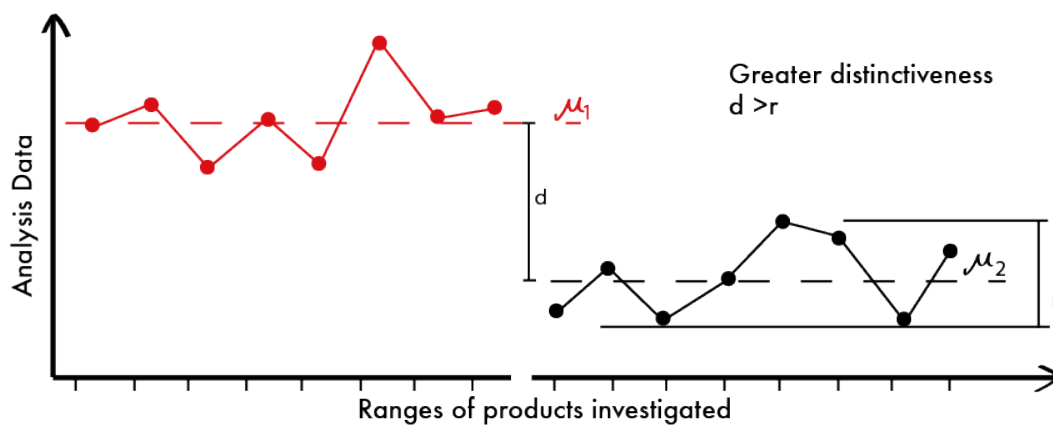
a) Examples of the use of variance to represent similarity and thus consistency across groups



b) Examples of evolutionary trends in a given characteristic across a range of products



c) Examples of a characteristic in which groups are said to be indistinct



d) Examples of a characteristic in which groups are said to be distinct

Figure 93 Illustrating the possible comparisons of degree of similarity to provide insights to support the styling process

10.2.3 Investigating distinctiveness in appearance

Distinctiveness through comparisons is relatively similar to degree of similarity calculations in that difference from the mean of a group (d) is considered with respect to the size of the bounding range of the group (r) (see Figures 78 – 81). The major difference is in the additional consideration of variance in product ranges.

Figure 93c illustrates a scenario where d is low with respect to the data range or variance of the two groups. Thus it can be said that one group is not distinct from the other for the characteristic in question. Figure 93d illustrates the same groups but in a scenario where they can be said to be distinct from one another. This is demonstrated by the greater difference between means compared with the data range or data variance.

This further consideration of distinctiveness in addition to consistency provides a mechanism to identify different styling strategies in consideration of a brands' current product range compared with competing brands. These are as follows.

- Consistent but indistinct – The scenario in which a company uses a similar feature appearance as its competition but maintains the same shape to generate familiarity.
- Consistent and distinct – The scenario where a brand uses a different or distinct feature appearance and maintains this across its product range.
- Inconsistent and distinct – This is the scenario where a brand makes feature appearance different to its competition but has little consistency (aside from the difference to competition).

In terms of competition, the analysis of these trends can be used to highlight aspects that may be viewed as strengths in styling strategy. They may also highlight a lack of any inclination in different characteristics that may be viewed as an area to increase consistency or an area in which design can be less conservative in order to become distinct.

Analysis of consistency and distinctiveness may also be applied to investigation of a product's history. However of key interest to the evolution of a product's appearance over its different generations are the changes in characteristics.

10.3 Further considerations in interpreting degree of similarity

Some further considerations made when interpreting degree of similarity to provide insights to support the styling process are now addressed. The first consideration concerns the products included in ranges and the implications on degree of similarity calculations. The second concerns the type of features that are compared readdressing comparison of equivalent and non-equivalent features raised in section 5.2.3.

10.3.1 Consideration of products included in bounding ranges

Comparisons can be investigated in two different contexts. The comparison of a product or group of products *against* another group of products or, comparison of a product or group of products *within* a group of products. The difference between these two instances is illustrated in Figure 94a and Figure 94b and concerns the inclusion of the product under investigation within the bounding range. As with 10.2, examples are given in reference to the degree of similarity calculations set out section 8.3, Figures 78 – 81.

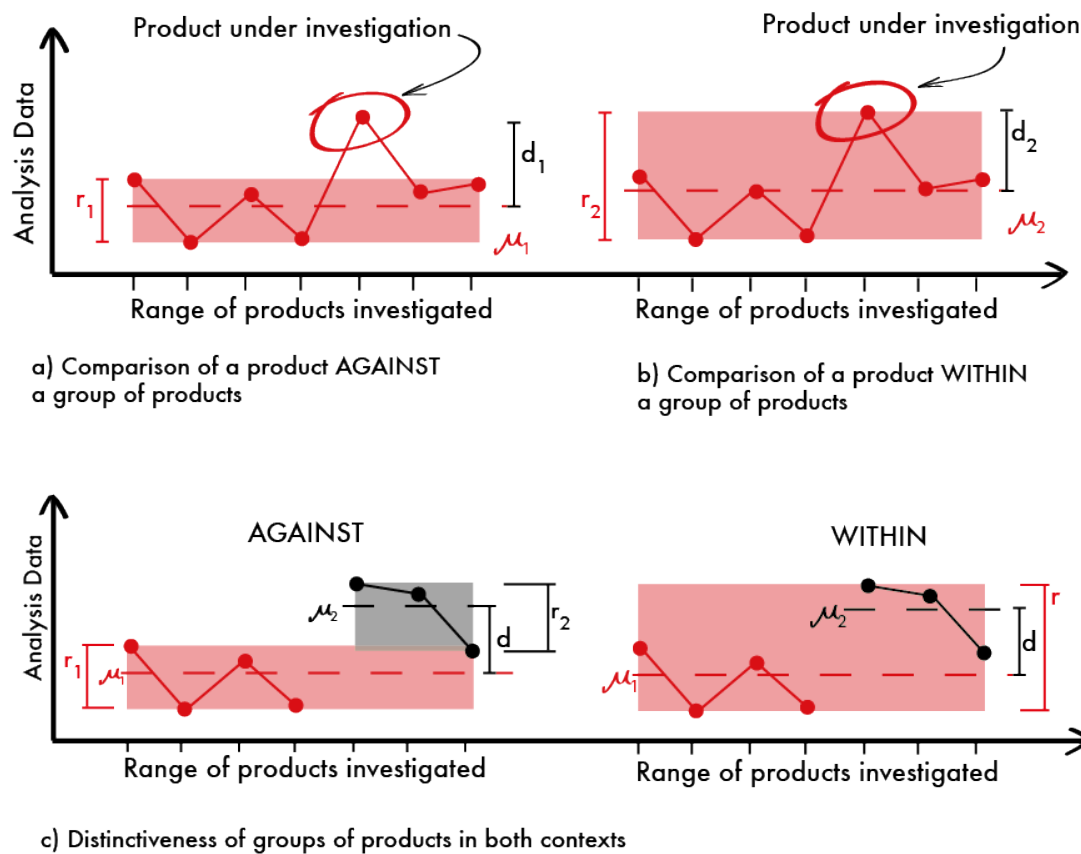


Figure 94 Illustrating different contexts of products investigated

Figure 94c reviews two scenarios with respect to the interpretation of distinctiveness. In the first (left hand side) scenario the products under investigation are not considered to be included in the bounding range (r_1). Conversely, the second scenario (right hand side) includes the products under investigation within the bounding range (r). In both scenarios case the difference (d) is calculated as the difference between the mean value for the two groups ($\mu_1 - \mu_2$).

10.3.2 Direct comparisons

The nature and type of features compared is now considered. As with the analyses proposed in section 8.1 direct comparisons and comparisons to a group are considered, beginning with direct comparisons. A product appearance being compared with another may have any number of constituent features. In this case, there are three possible direct comparisons that may be assessed:

1. Equivalent features between two products
2. Non-equivalent features between two products

3. Non-equivalent features within one product

Equivalent features are features that are deemed to be the same in terms of function and or the visual impression they create. Non-equivalent features are those deemed as fulfilling a different function and/or visual impression. These three basic comparisons are illustrated in Figure 95.

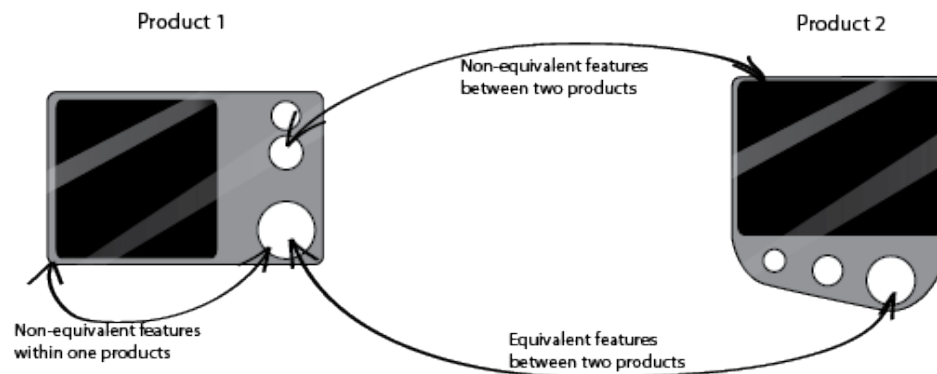


Figure 95 Possible direct comparisons between features

10.3.3 Comparison to groups

The direct comparison can be extended to investigate the degree of similarity of a given feature. Thus the direct comparisons may also be extended to consider the comparison of a feature against a group of features. In comparison of features across groups, it is possible to compare a feature to equivalent features in a group of products, or a feature to non-equivalent features in a group of products.

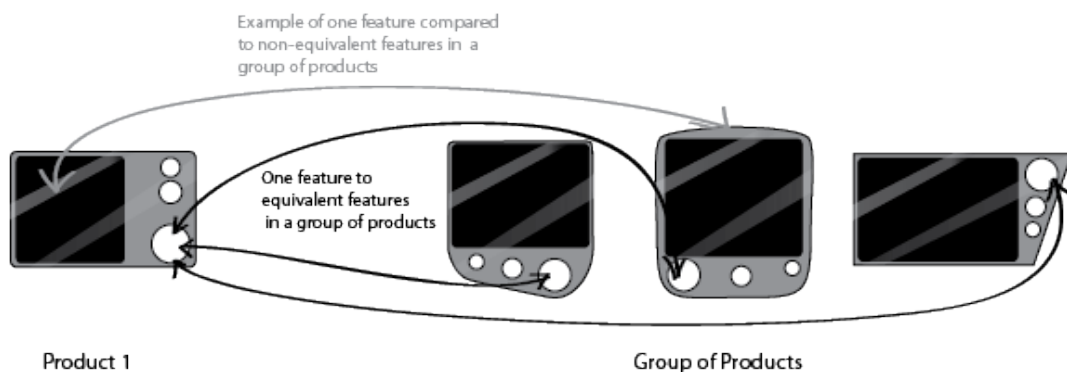


Figure 96 Possible comparisons between features in groups of products

In addition to comparing one feature to a group of features, comparisons can be extended to be made between two groups of features. Possible comparisons are similar to those of an individual to a group and involve equivalent features of a one group of

products to another group of products or non-equivalent features of a one group of products to another group of products.

10.4 Guidelines for using measurements of similarity in appearance to provide insights to support the styling process

Table 9 combines the considerations discussed in 10.2 – 10.3 to create a guideline for further interpretation of degree of similarity contended to best provide insights to support the styling process depending on the context of products being investigated. These guidelines provide the final step in the overall method to measure and compare product appearance subsequently presented in 10.5.

Product space	Use of degree of similarity	Context of ranges	Features compared
Current	Consistency	Comparisons within range	Equivalent and Non-equivalent features
Previous	Consistency Evolutionary trends	Comparisons within range	Equivalent
Competition	Models Distinctiveness Consistency	Comparisons within range	Equivalent
	Ranges Distinctiveness Consistency	Comparisons against range	Equivalent and Non equivalent (within brand groups only)

Table 9 Guidelines for analyses of most use/best support to designers

Table 9 provides a look up table that can be used to consider the context of products and subsequently define the details of the way in which the method proposed at the end of this chapter is to be applied. As such this table forms the first key stage in the overall method to measure and compare product appearance. As such it also defines

the final key stage in that it provides the rationale for selecting the degree of similarity data which reflects the particular comparisons proposed to give insights to support styling. In other words the criteria for picking out data that is ‘useful’ for designers.

The table is used by first selecting the location of a product(s) in the product space (column 1). Given this, the type of trend to be interpreted from degree of similarity calculations is defined (10.2) along with further considerations such as the grouping to calculate the bounding range (r), and possible features to compare (10.3).

10.5 Overall method to measure and compare product appearance

The overall method to measure and compare product appearance is now presented in Figure 97. It highlights the key stages and the processes involved in each stage along with major inputs and outputs. The majority of key stages are the same as those presented in the method to measure similarity in appearance in Figure 83. The crucial addition which has resulted from the research in this chapter is the consideration of product context which is embodied in the first stage of the method. This stage provides the user with information necessary to select products and features against which to make comparisons of appearance. Consequently this first key stage is also used to define the rationale for how data on degree of similarity of appearance is interpreted to best provide insights to support the styling process.

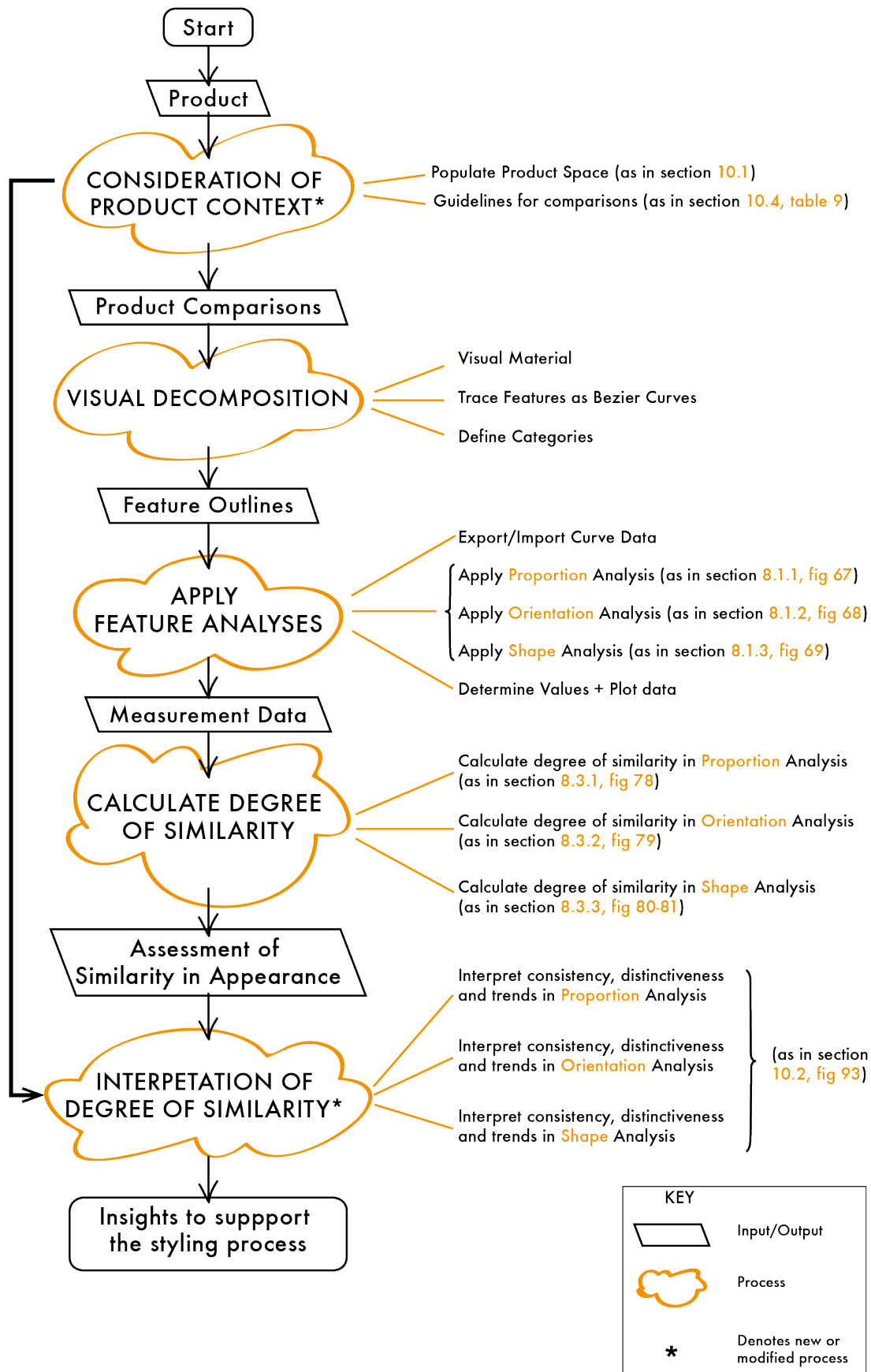


Figure 97 Overall generic method to measure and compare product appearance NOTE the additional stages added to the generic method to measure similarity in product appearance proposed in chapter 8 (Figure 83)

10.6 Concluding remarks

This chapter reports the further interpretation of degree of similarity to provide insights to support the styling process in comparing appearance. This is achieved through discussion of designer's requirements (raised in 3.3 and 4.3) in relation to the context of products investigated, and thus how the degree of similarity data may be interpreted to generate data that assists with the evaluation of these requirements. The resulting guidelines for interpreting data (Table 9) form the final stage in the overall method to measure and compare product appearance presented in full in Figure 97.

In addition to proposal of the overall method to measure and compare appearance, a further major contribution of the chapter is in the guidelines provided in Table 9. These add two key stages, completing the overall method. The value of these stages is in first providing the strategy for using objective data to evaluate and rationalize about designs in different scenarios faced by designers during the design process.

Thus further interpretation (the additional last key stage) may be used to highlight and assess adherence to visual references to brand in current products. Comparisons in previous products may be used to forecast and inform evolution of design language as well as reinforce visual references to brand. When comparing competing products, further interpretation can be used to provide insights on areas of distinctiveness and recommend aspects of appearance in which distinctiveness can be promoted to improve recognition in the marketplace. Having proposed a finalized overall method, it is implemented in a case study in the following chapter.

11 CASE STUDY 2: APPLYING THE METHOD TO MEASURE AND COMPARE PRODUCT APPEARANCE

This chapter describes the application of the overall method to measure and compare product appearance to conduct an in depth study into the appearance of vehicles manufactured by BMW. Whereas the testing of the initial method included a limited number of products, this study explores the appearance of 40 vehicles populating the product range, product history and competing brands dimensions of the product space.

The chapter begins by presenting the implementation of the overall method to measure and compare appearance in Figure 98. The various stages of this implementation are next addressed beginning by discussing the selection of vehicles as a test subject and the rationale for applying the analyses to the graphics features in the front view or ‘fascia’. The details and contexts of the vehicles are also discussed with respect to the product space. The application of the visual decomposition stage is next included. This discusses the steps taken to obtain the images that form the basis of the study, the application of feature analyses and calculation of degree of similarity is then addressed followed by the interpretation of outputted data to generate insights contended to support BMW styling process.

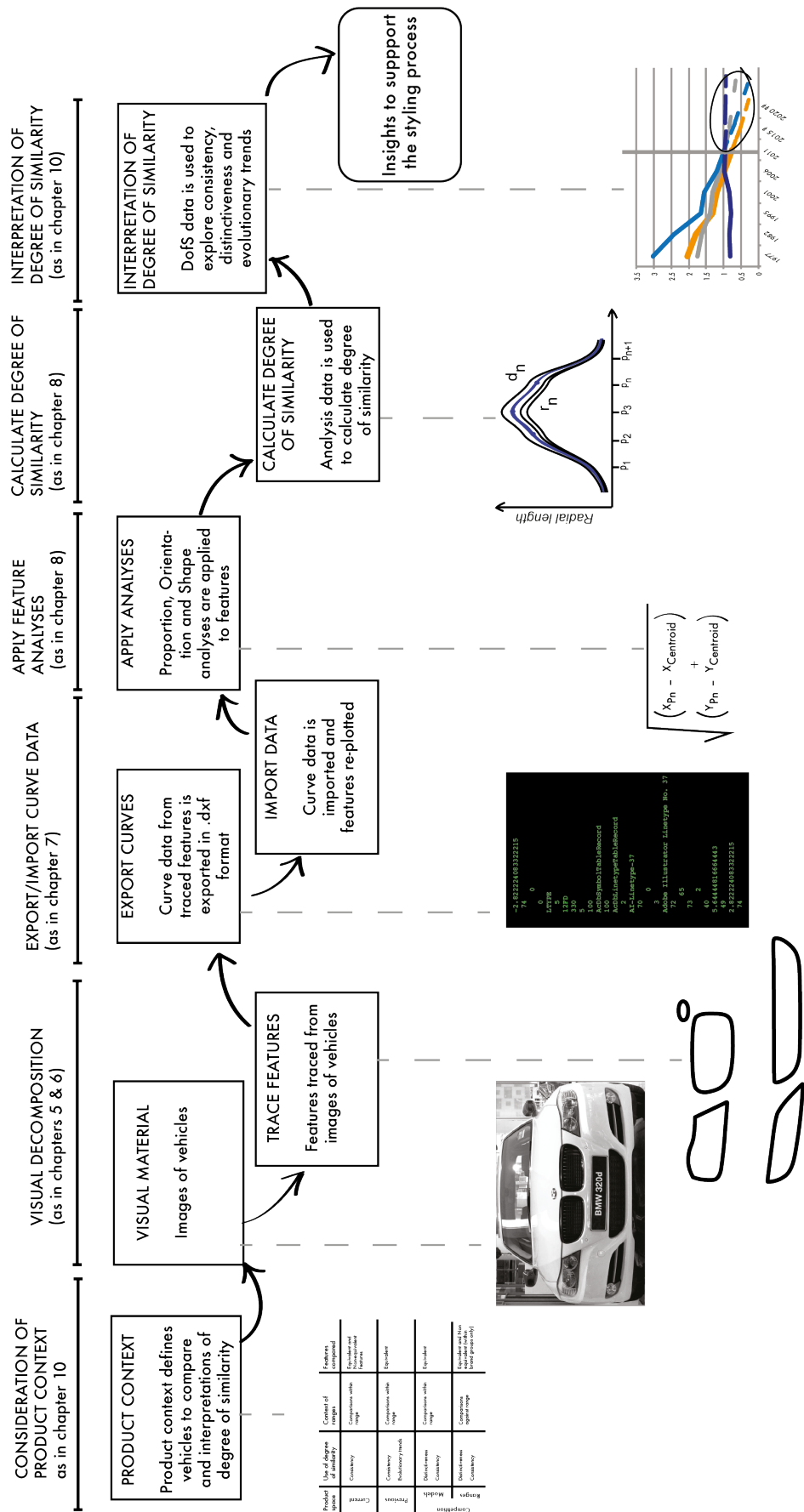


Figure 98 Steps followed to apply the generic method to measure similarity in product appearance presented in the previous chapter (Figure 97)

11.1 Consideration of product context: Vehicles investigated

One of the reasons for applying the initial method to smartphones (chapter 9) was the relative similarities and simplicity in features. In contrast vehicles include greater variety in terms of the complexity of shapes as well as the position and relative proportion of features.

From the overall vehicle appearance, the front view is the focus of this case study and in particular the graphics features. This is because they have been shown in chapter 6 as being most influential to brand recognition and thus of clear importance to designers with respect to visual branding. A further contributing factor relates to the use of images and the subsequent interpretation of feature boundaries discussed in 7.6. The boundaries of graphics features have been shown (chapter 5 and 6) to be relatively easy to define which in turn makes for more reliable results.

11.1.1 Selection of BMW as the primary brand

The primary brand studied in this case study is BMW. This brand is chosen as the focus/base for investigation for a number of reasons. Firstly BMW vehicles are often classed as iconic in terms of design (Karjalainen and Snelders, 2010) and (as shown in section 6.2) are recognizable by appearance, and thus the brand/manufacture place particular importance on appearance/aesthetic design (BMW, 2012). Additionally BMW have a degree of variety in appearance and have, over generations, implemented relatively distinct changes in design while maintaining characteristic styling and positive perception of appearance (Bangle, 2001, BMW, 2012). Thus it is the balance between the use of iconic features or visual references to brand and diversity among the product range and over previous generations that makes this brand of particular interest for testing the method to measure and compare product appearance.

11.1.2 Vehicles investigated: populating the product space

The context of vehicles investigated are plotted in within the product space derived in section 10.1 (Figure 99).

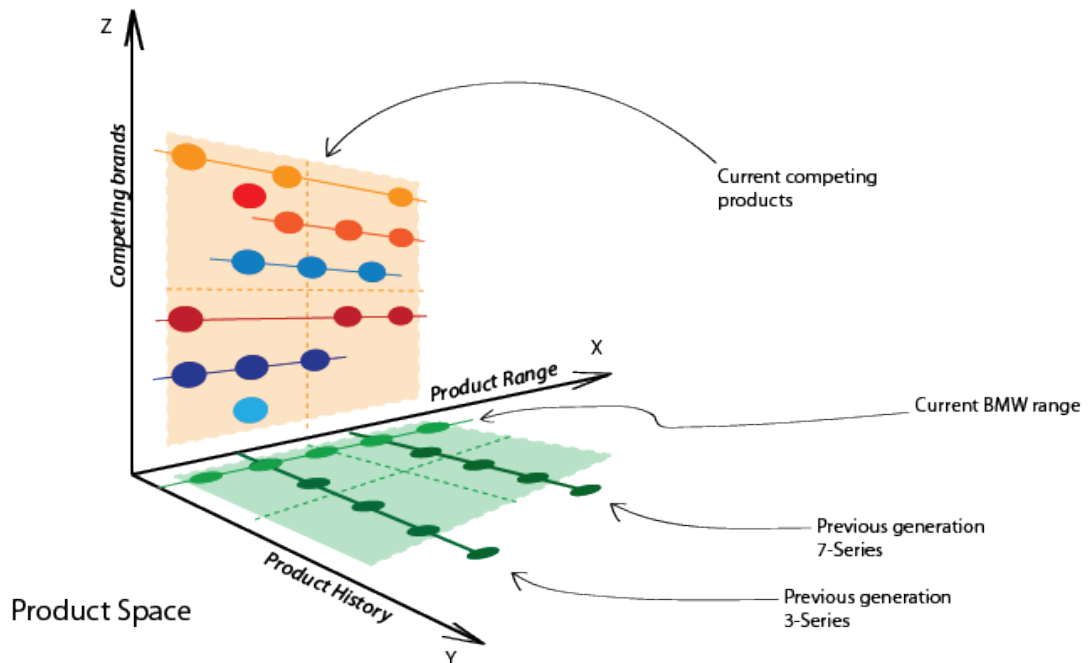



Figure 99 Illustrating the context of the types vehicles investigated in terms of the product space


Vehicles from the current BMW range populate the X-axis (product range). Consequently the X-Y (past) plane is populated by the previous generations of two models, the 3-series and the 7-series.

The vehicles included in the X-Z (competition) plane are selected by three criteria: directly competing vehicles, directly competing brands, and other vehicles. ‘Direct’ refers to vehicles that retail at similar price, offer similar specification and are generally considered by manufacturers and the media to be a logical alternative. The competing vehicles are those in direct competition with the BMW 3-series and BMW 7-series and include Audi and Mercedes Benz. Finally a number of other vehicles are also considered in the competition space which, although less likely, could be purchased as alternatives to various BMW vehicles. A list of the 40 vehicles assessed is included in Table 10.

BMW	Current	1-Series 118i * 1-Series 135i 3-Series 320d * 3-Series 335i 5-Series 530d GT 5-Series 535d * 7-Series 720d * X3 X5m Z4 35i
	Previous	1977 3-Series 1982 3-Series 1995 3-Series 2001 3-Series 2006 3-Series 1977 7-Series 1987 7-Series 1995 7-Series 2002 7-Series 2006 7-Series 2009 7-Series
Competition	Audi	A3 A4 A6 A8
	Mercedes	C-Class E-Class CLS - Class S-Class
	Other brands	Volkswagen Golf Volkswagen Phaeton Ford Focus Ford Mondeo Jaguar XJ Jaguar XF Lexus IS Lexus GS Toyota Prius Honda Accord Porsche 911

Key

 Models in direct competition with BMW 320d

 Models in direct competition with BMW 720d

* BMW models included in comparisons with Audi and Mercedes ranges

Table 10 Vehicles used in the case study

11.2 Visual decomposition

Images are specified using guidelines developed from the previous work discussed in chapter 7. This section includes the method used to create original images along with images from external sources. The systematic error in tracing vehicle features from these image types is also determined.

11.2.1 Original images

In consideration of the creation of original images, issues of lens distortion and parallax are known to affect the resulting image. Thus steps are/should be taken to minimize inconsistency due to these factors by keeping the camera lens and position of the camera constant for all original images. The test rig designed to maintain constant camera position is illustrated in Figure 100.

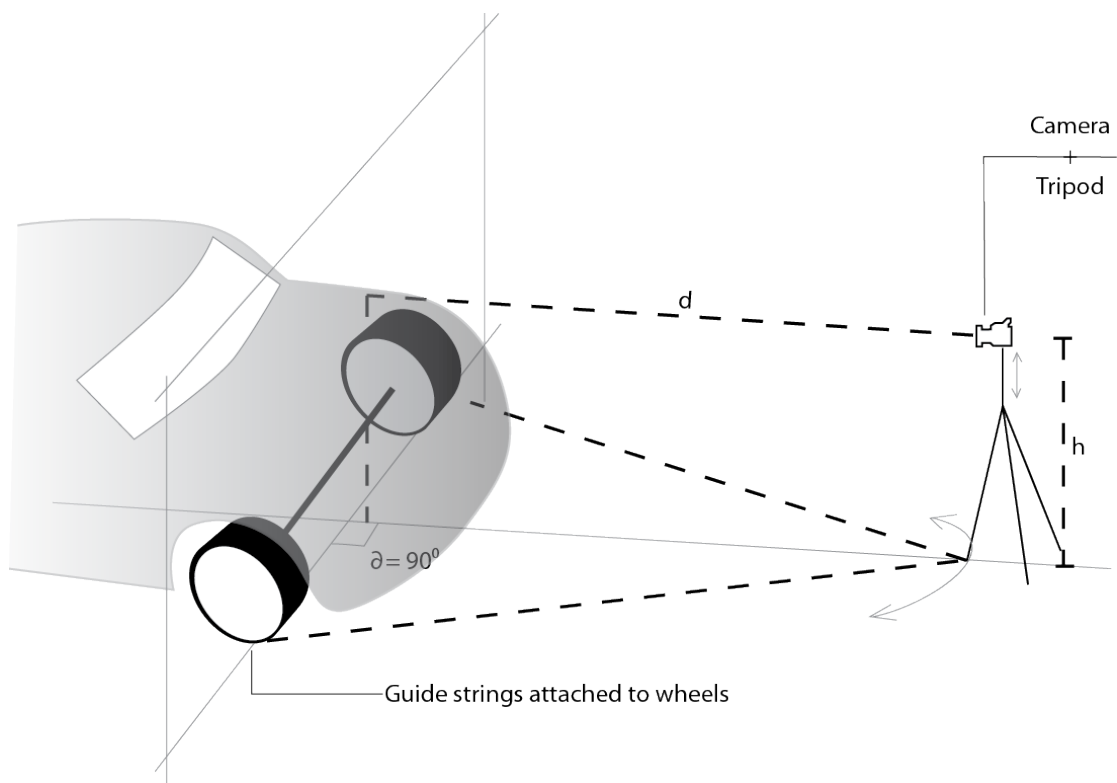


Figure 100 Rig used to generate first hand images of vehicles

The images were taken using a 50mm lens at a distance (d) of 3.5m from the front wheels and a height of 0.75. The images were high resolution, 3776 x 2520 pixels. The effect of different heights on images was kept consistent, however the effect of doing so is investigated as part of error testing.

11.2.2 Images from external sources

Due to the large number of vehicles included in this study and their variety, it was not possible to gain access to all of the vehicles and obtain original images. Images of the complete current BMW range were captured first-hand. However remaining images had to be obtained from other sources where the various settings used in the creation of these images is unknown. Thus the effect of using images from external sources also had to be assessed.

In gathering external images steps were taken to obtain images as close to the given guidelines as possible. Hence maximum possible resolution images that, from inspection, had minimal lens distortion and the most precise front elevation, were selected.

11.2.3 Measurement of error in visual material

The measurement of error associated with first-hand image capture, use of external images and the tracing method for vehicles is now determined and the method of evaluation for each class of image is summarised.

Error in original images

Original images for the BMW 320i and BMW 320d, different vehicles with identical fascia designs, were gathered. The method adopted is summarized in the following steps and illustrated in Figure 101.

1. Rig set up as in Figure 100 and a number of images were taken subtly varying the angle within the constraints of the guides.
2. This was then repeated at a lower camera height (h) of 0.63m, the mid height of the lowest vehicle (as opposed to the mean height).
3. The features were isolated, all analyses applied and degree of similarity in each analysis calculated.

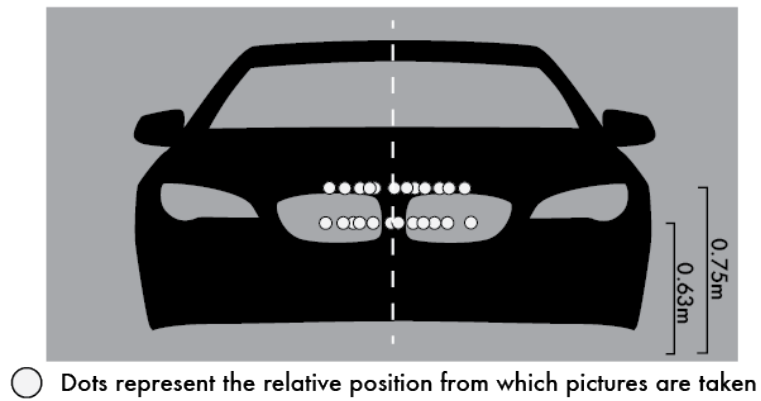


Figure 101 Illustrating the different relative camera positions used to test for inconsistencies associated with first-hand image capture

Error in external images

In this test a first-hand image is compared with that of a lower resolution and quality image. Thus an image of a BMW X3 taken using the specifications set out in 11.2.1 was compared with an image obtained from BMW promotional material. The external image was scaled/zoomed to occupy the same image size as the first-hand image, illustrated in Figure 102. As with the first-hand error test, analyses were applied and similarity calculated.

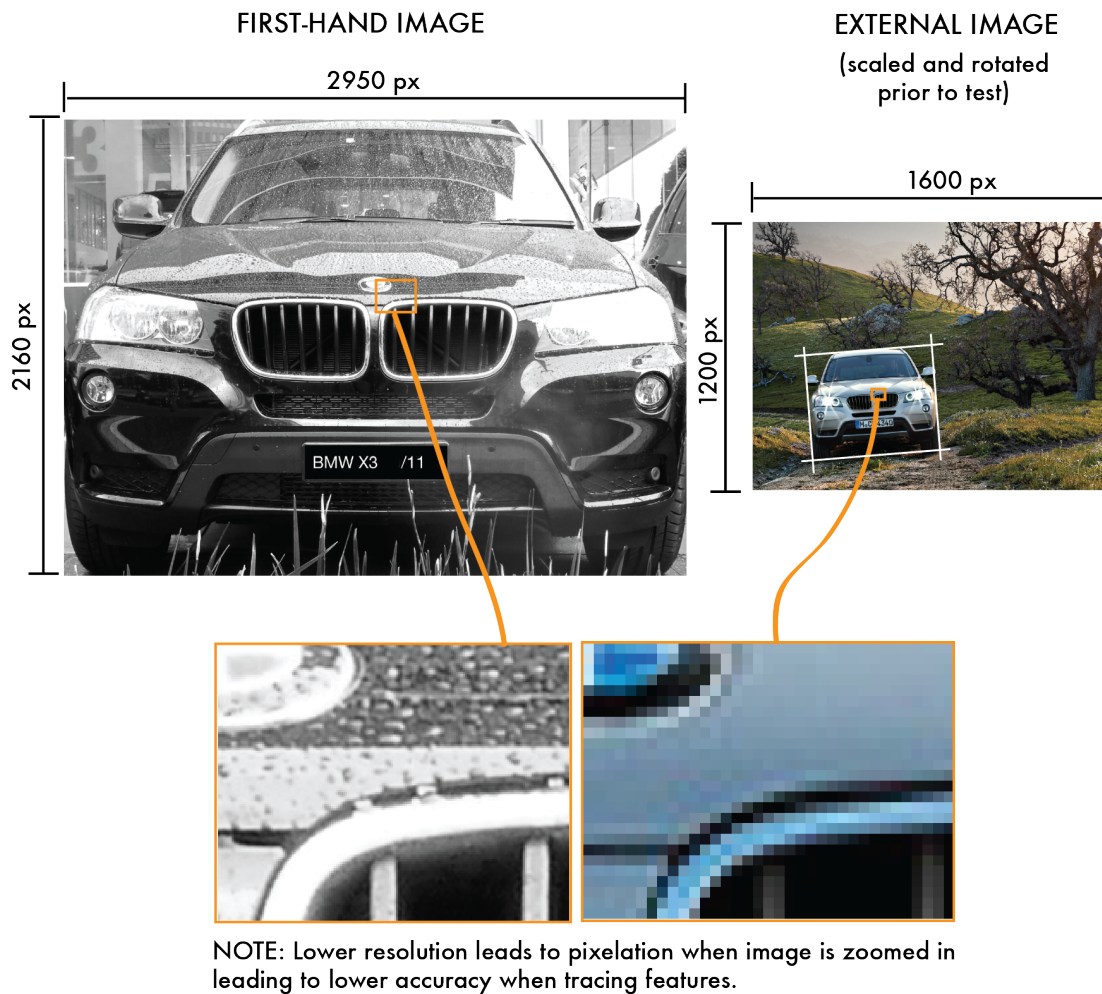


Figure 102 Illustration of the different images used in comparison of first-hand and external images

Systematic error in tracing vehicle graphics

The same method as that used in the exploratory study (7.6.3) was applied to a single original image to test systematic error in tracing vehicle features. In summary, the features were traced multiple times and the inconsistencies between tracings assessed by applying analyses and calculating the degree of similarity.

11.2.4 Calculated error

The maximum error calculated associated with the two classes of image is shown in the first two columns of Table 11, the third column shows the proportion of this error which is shown to be due to systematic error in tracing.

		Repeated capture of original images	Comparison of an external image to an original image	Systematic error in tracing vehicle features
MAX. Error	Proportion analysis	3.32%	4.69%	1.27%
	Orientation analysis	3.96%	5.09%	4.40%
	Shape analysis	6.03%	11.58%	6.70%

Table 11 Summarising maximum error calculated for different aspects of the base images used in this case study

Of the three tests it can be seen that the greatest error is associated with the use of external images. Of the three types of analysis it can be seen that the shape analysis is most prone to error. It is also observed that between original images there is an appropriately small error related to image capture method.

Original images are used in the review of vehicles from the current range of vehicles. It is contended that these vehicles and their features are likely to be most similar thus it is appropriate that the highest accuracy will be applied when analysing the product range. Vehicles compared using external images are from competing brands and previous product generations which is considered appropriate as there is less similarity between vehicles and features. As such the lower levels of accuracy associated with the use of this type of base image is of less consequence when overall similarity is also lower. Notwithstanding the above it is considered that a total error of 11.58% is adequate.

11.2.5 Tracing features

As defined in 5.3.1 the graphics features of badge, grille, headlight, lower side intake and fog-light cluster (LSIC) and central intake (CI) are investigated. The isolation of these features is illustrated in Figure 103.

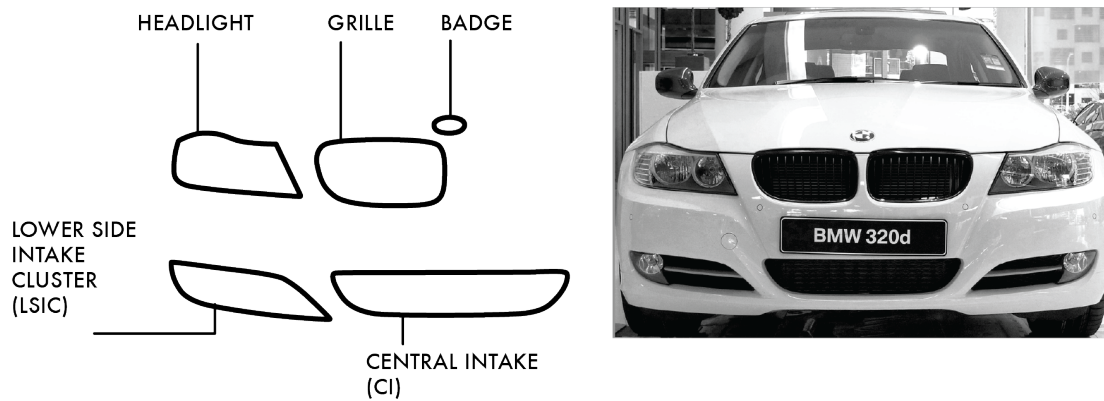


Figure 103 Visual decomposition applied to graphics features in the vehicle fascia

It is noted that the BMWs use a split ‘kidney-grille’. This is assumed to be symmetrical and thus only one side is investigated. Similarly the headlights and LSIC are assumed symmetrical about the vertical centre, thus only one side is considered.

Boundaries of features are defined as set out in chapter 5. There are some instances where boundaries require some subjective judgment as there is no obvious change in material or part. This, although not precise, is only a symptom of the requirement to use images but given the controlled acquisition of images the uncertainty is reduced. Furthermore all tracing was undertaken by the author to improve consistency of judgements.

11.3 Application of feature analyses and calculation of degree of similarity

As in previous chapters, the three feature analyses (proportion, orientation and shape) are applied to the graphics features. The badge feature is used as a reference point as such its shape and proportion analysis are not further considered. This is done for a number of reasons.

Firstly their appearance is consistent for BMWs and thus no value in their comparison across the BMW range. The second reason is that it does not require objective evaluation during the design process in the same sense that the other features do. Its design is often a rebranding exercise approached from a graphic design perspective.

More often than not it is not the designer's prerogative to consider or change the design of the badge.

The badge is selected as a reference as it is assumed to be completely central in the X-axis and fairly central in the Y-axis. This is an important consideration as its centrality means lens distortion and camera position has the least effect on its relative position. It is also common in that it features in all vehicles reviewed in a largely similar location. Other features could be used such as a wheel or windshield, however, they are all in, or partly in, more extreme positions and hence can be more greatly affected by factors of parallax or lens distortion (11.2.4).

The limitation of the use of the badge is that, when considering orientation across competition, features may appear skewed. This can be rectified by normalizing/translating features manually to compare orientation relative to another feature.

In terms of obtaining data from decomposed features, the same software applied in chapter 7 is used. In summary features are traced as chains of Bézier curves. Traced features are imported into the software as .dxf files and analyses are applied. Measurement data is then output in order that similarity calculations may be used in line with the refinements proposed in the previous chapter (10).

11.4 Results: Interpreting degree of similarity

The sample of vehicles used results in a total of 140 features each of which has three analyses applied. The results from this application are then compared using the guidelines presented in Table 9 considering multiple contexts (consistency, trends and distinctiveness) each of which is done using a different chart/plot. Due to the substantial quantity of data created only charts that demonstrate only most notable trends are presented in this section. Thus results are summarized in Table 12 - Table 14 which include particularly significant plots. Table 12 give results and interpretation of trends with reference to the 'current' (top) row in Table 9, while Table 13 refers to the 'previous' row and Table 14 refers to the 'competition' rows. The results reported in the tables are also illustrated (Figure 104 - Figure 108) in terms of vehicle appearance

and the context in which they are important to designers. Appendix 2 includes further examples of notable results plotted in charts.

PROPORTION ANALYSIS	ORIENTATION ANALYSIS	SHAPE ANALYSIS
<p>Consistency in proportions in width and perimeter. Particularly in relationships between Grille, Headlight, and CI. (coeff. var approx 0.004 - 0.02, one order of magnitude less than other relationships)</p>	<p>Consistency in Grille maximum (X,Y) with variance 0.1, 2.9 Grille centroid and all Headlight Y coordinates are relatively consistent with variance averaging 6.8</p>	<p>Grille and Headlight are most consistent in terms of shape. Where the grille has two major sections of variation the headlight is more consistent in places but has greater fluctuation. LSIC and CI are approximately 2.5 and 4 times as inconsistent.</p>
<p>Coefficient of variance in proportion analysis</p>	<p>Variance in orientation</p>	<p>Coefficient of variance in shape analysis</p>
<p>TRENDS ILLUSTRATED IN FIGURE 104</p>		
<p>TRENDS ILLUSTRATED IN FIGURE 105</p>		

Table 12 Summary of results from analysis of the CURRENT BMW product range

PROPORTION ANALYSIS	ORIENTATION ANALYSIS	SHAPE ANALYSIS	SUMMARY
<p>Major evolutionary trend is observed in all proportions between the grille and headlight except in height which is constant. Height proportions across other features is consistent (coeff var 0.005 - 0.06)</p>	<p>Evolution in growing distance of grille and Headlight X coordinates. Reflecting the trends seen in proportion analysis. Consistencies in Grille maximum position and Headlight Y coordinates Consistencies in the Y maximum for LISC and CI</p>	<p>An overall evolutionary trend is observed in features becoming less 'boxy' and more organic in form. This is most pronounced in the Grille which also exhibits a step change between models from 80's to 90's. Sections in the contour of Grille and headlights are observed as being particularly consistent despite the evolution in shape. (coeff. var approx 0.05 in places)</p>	<p>CHARTS</p>
<p>Proportions between grille and headlight</p>	<p>Centroid Relative position</p>	<p>Coefficient of variance in shape analysis</p>	

TRENDS ILLUSTRATED IN FIGURE 106

TRENDS ILLUSTRATED IN FIGURE 107

Table 13 Summary of results from analysis of the PREVIOUS BMW vehicles

SHAPE ANALYSIS	SUMMARY		CHARTS
	Models	Ranges	
PROPORTION ANALYSIS	Distinctiveness in shape (d) is not observed to be greater than the SD along feature contours. In observation of non equivalent features it is seen that similar shape plot patterns are seen through BMW Grille, Headlight and LSIC for models investigated. This pattern is not seen competing models.	Shape plots are largely similar (low var.). They do highlight slight differences/nuances in shapes around shape plot peaks. Coeff of var plots show sections on features contour where variance 'spikes'. Illustrating points on the contour where shapes vary. These spikes are in different locations for different brands and different features. The width of the LSIC is shown to be greater than that of a number of brands but not larger than all.	<p>Coefficient of variance in shape analysis</p> <p>— Audi coeff Var. — Mercedes coeff Var. — BMW coeff Var.</p>
	Distinctiveness is observed in the Y axis for all features due to relative position of the the Badge. However distinctiveness in LSIC and CI is of greater magnitude than that influenced by the badge position. The LSIC and CI are positioned lower than competitors and by magnitude (d) greater than the SD	Distinctiveness is observed in the Y axis for all features and particularly in LSIC and CI. In addition it is seen that these positions are substantially more inconsistent across the BMW range compared with competing brand ranges.	
ORIENTATION ANALYSIS	Relationships between Headlight, LSIC and CI are not distinctive from competing models.	Average relationships between Headlight, LSIC and CI are not distinctive from competing ranges, nor are they different in terms of consistency. Consistency across all ranges is particularly high in Perimeter and Width proportions (coeff var 0.12).	<p>Coefficient of variance in proportion analysis</p> <p>— Coefficient of variance - audi range — Coefficient of variance - Mercedes range — Coefficient of variance - BMW range</p>
	Distinctiveness is observed in the Y axis for all features due to relative position of the the Badge. However distinctiveness in LSIC and CI is of greater magnitude than that influenced by the badge position. The LSIC and CI are positioned lower than competitors and by magnitude (d) greater than the SD	Distinctiveness is observed in the Y axis for all features and particularly in LSIC and CI. In addition it is seen that these positions are substantially more inconsistent across the BMW range compared with competing brand ranges.	
SHAPE ANALYSIS	Distinctiveness is observed in the Y axis for all features due to relative position of the the Badge. However distinctiveness in LSIC and CI is of greater magnitude than that influenced by the badge position. The LSIC and CI are positioned lower than competitors and by magnitude (d) greater than the SD	Distinctiveness is observed in the Y axis for all features and particularly in LSIC and CI. In addition it is seen that these positions are substantially more inconsistent across the BMW range compared with competing brand ranges.	<p>Difference from mean in orientation</p> <p>— BMW 3 Series difference from mean (d) — Standard deviation of competition (SD)</p>
	Distinctiveness is observed in the Y axis for all features due to relative position of the the Badge. However distinctiveness in LSIC and CI is of greater magnitude than that influenced by the badge position. The LSIC and CI are positioned lower than competitors and by magnitude (d) greater than the SD	Distinctiveness is observed in the Y axis for all features and particularly in LSIC and CI. In addition it is seen that these positions are substantially more inconsistent across the BMW range compared with competing brand ranges.	

TRENDS ILLUSTRATED IN FIGURE 108

Table 14 Summary of results from analysis of the BMWs and other COMPETING vehicles

Results summarized in Table 12 - Table 14 are now related to features in vehicle appearance illustrated in Figure 104 - Figure 108.

Current range

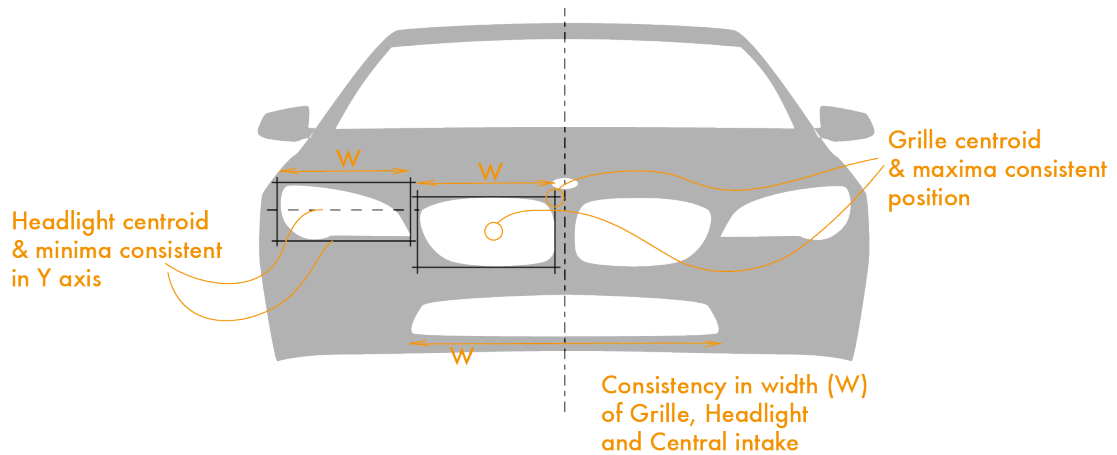


Figure 104 Illustration of observations from proportion and orientation analyses related to vehicle appearance given in Table 12

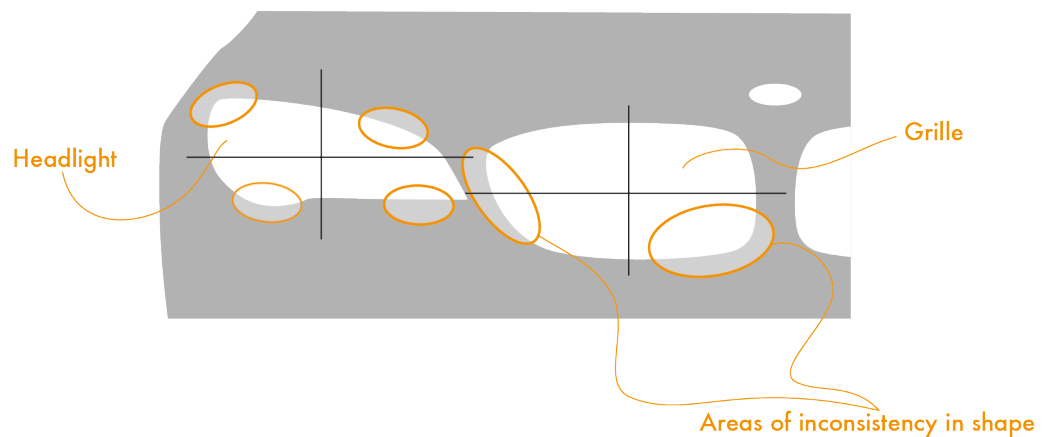


Figure 105 Illustration of observations from shape analysis highlighting the areas of inconsistency in grille and headlight contours given in Table 12

From review of consistencies in the the current BMW range (Table 12) it is shown that there are major consistencies in the interrelationships between widths of the grille, headlight and CI (Figure104) and in particular sections of the grille and headlight contour/outline shape (Figure 105). This data indicates these areas of consistency embody visual references to brand through their repetition of geometry throughout the range.

Previous models

From the previous analysis (Table 13) it is shown that some of the consistencies seen across the current range are also manifested through the previous models of BMW 3 and 7 series, namely in the relative position of the grille and headlight and sections of the grille shape (Figure 106 - Figure 107). This indicates particularly strong references to brand through the persistent use of similar/unchanging geometry.

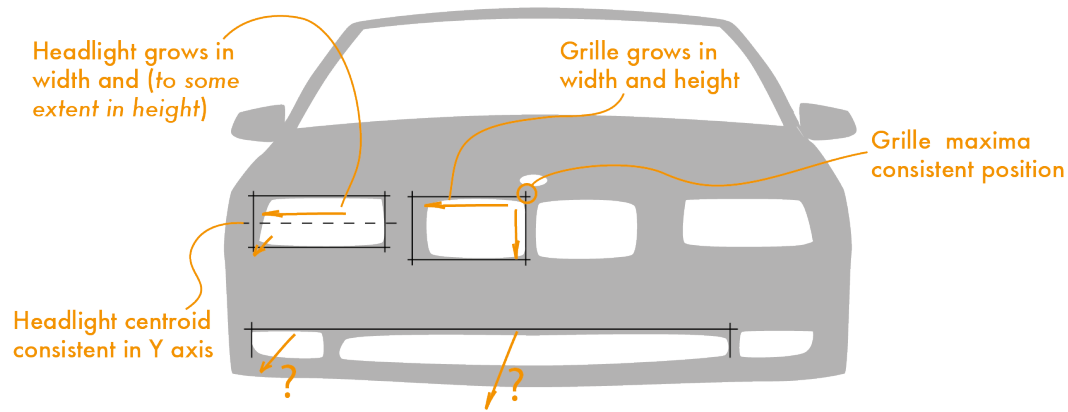


Figure 106 Illustration of observations from proportion and orientation analyses related to vehicle appearance given in Table 13

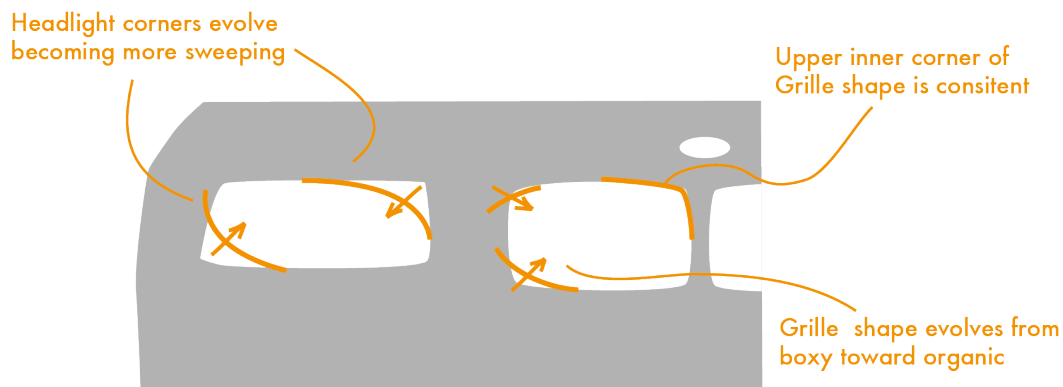
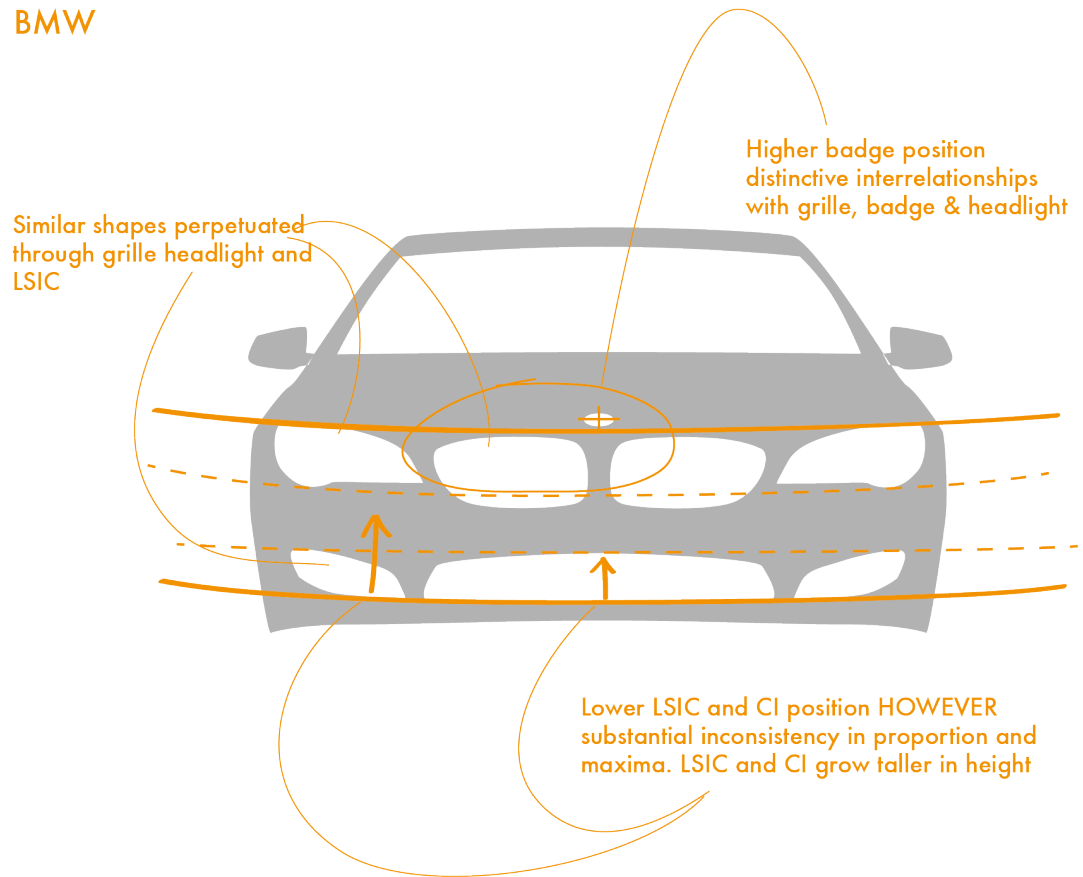


Figure 107 Illustration of observations from shape analysis highlighting the areas of inconsistency in grille and headlight contours given in Table 13

From this comparison it is also seen that there are trends in evolution of geometry. It is revealed that the proportion between headlight and grille features are growing in width while their shapes are becoming increasingly more organic.

BMW



COMPETITION

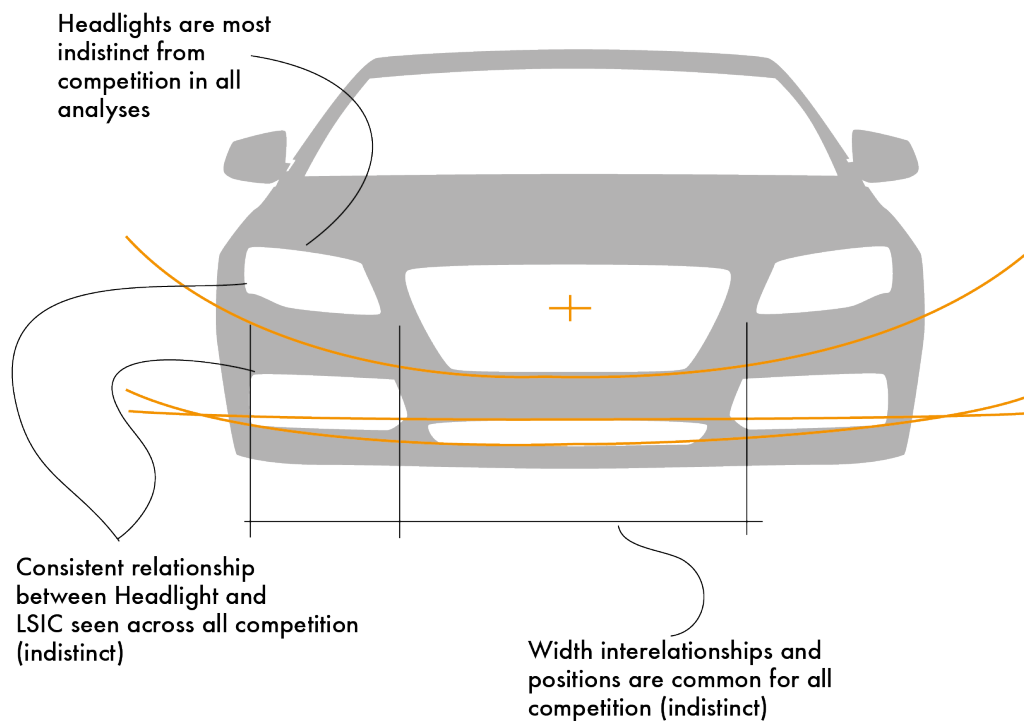


Figure 108 Illustration of observed distinctiveness and consistencies comparing BMW vehicles to competing vehicles given in Table 14

Competition

From comparisons with competing vehicles it is shown (Figure 108 and Table 14) that the major distinctiveness in BMWs is observed in the relative positional relationships between the badge, grille and headlight features. The LSIC and CI are distinct in the location of the minima but also demonstrate distinctiveness through the variety of shapes within the BMW range. Features consistent across the majority of vehicles studied are also noted.

11.5 Providing insights to support the styling process

The results from the application of the method are now discussed from the point of view of ways they may be used to provide insights to support the styling process during the styling process. It is contended that the provision of objective data on similarity is in itself is of use to designers as illustrated in the first case study. However the major support for designers is in further interpretation from basic similarity. In this case study data on degree of similarity is further interpreted with respect to three types of trend now discussed.

Consistency

Investigating current range and to some extent competing ranges, variance is calculated to give numerical values for consistency in appearance. The value to designers from providing such data on consistency is twofold. Within the current range it can be used to first highlight and subsequently measure adherence to visual references to brand. Thus when evaluating novel designs, data on consistency can be used to provide an objective measure as to the degree to which the novel design utilizes/embodies such references to brand. In terms of the observations made in this case study, the data on consistency forms a ‘datum’ for the geometry of the headlight and grille against which a new vehicle design can be measured and subsequently reasoned about.

With respect to the competing products/vehicles, calculation of consistency is of particular use to designers as it helps to review the consistency with respect to other

brands. This is of particular value as it can be used to identify if a consistency observed within a brand is also seen across the competition. This in turn can be used to suggest whether geometry is indicative of a particular brand or simply archetypal across the entire market.

An example of this in the results is seen in the headlight feature. While the geometry is particularly consistent across the BMW range it is also consistent across competing brands. This would indicate that the headlight geometry is archetypal across the executive saloon sector and thus indistinct.

Evolutionary trends

By investigating previous generations of models, degree of similarity calculations are used to numerically identify and assess evolutionary trends. The major value in this is in being able to plot/visualize the evolution of design language, and as such extend plots to review the trajectory of design language. Thus as with measures of consistency, a form of datum is produced against which novel concepts may be compared and subsequently reasoned on objectively.

In terms of results gained from this case study, an example of such support is demonstrated in the trend seen in proportions between the headlight and grille. Figure 109 illustrates this showing the way in which trends can be used to create a trajectory for future designs. This trajectory may then be used as a datum against which novel concepts may be reviewed.

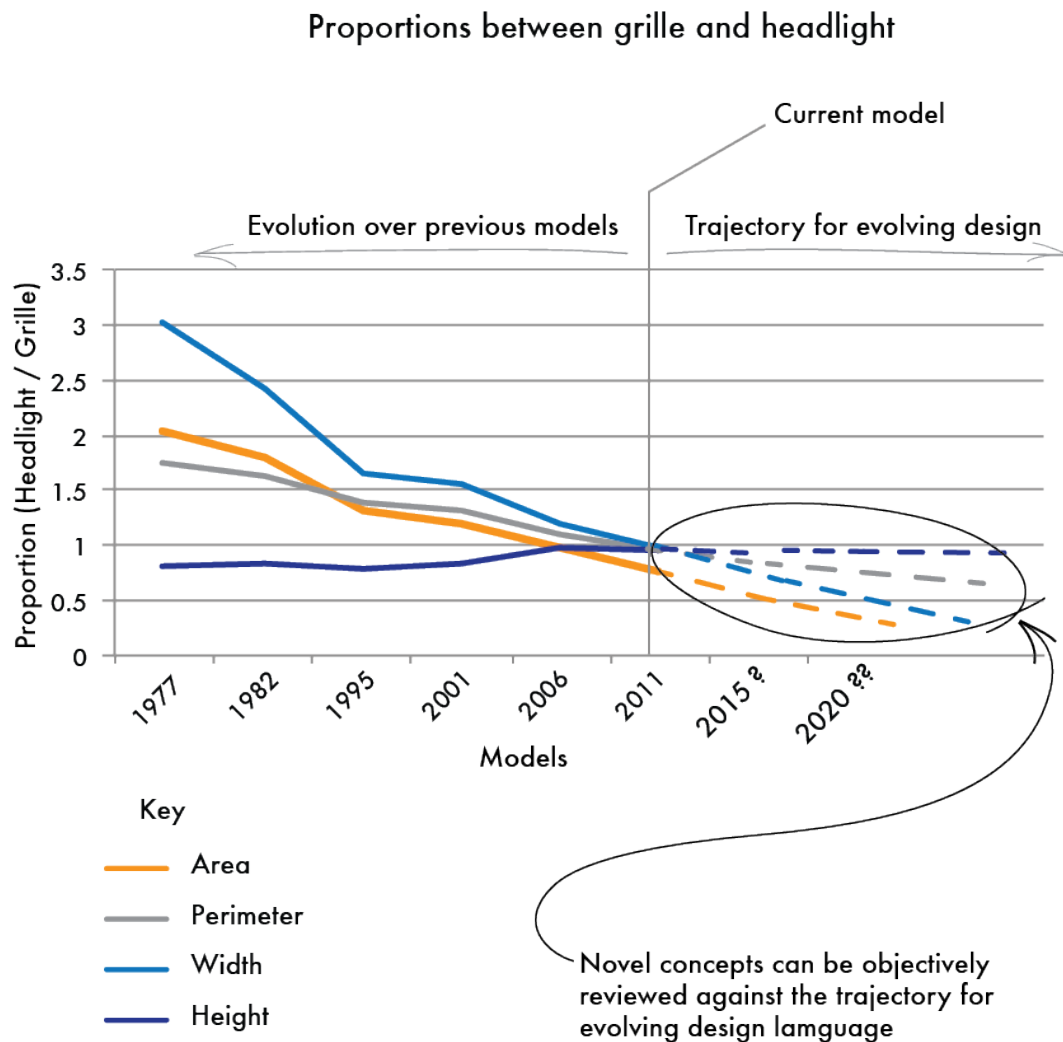


Figure 109 Demonstration of the use of plotting evolutionary trends

Distinctiveness

Analysis of distinctiveness is of particular use in evaluating strategic differences or similarities with regard to competing products. Distinctiveness may be observed in terms of consistent differences in geometry from competing products. It may also be observed through significant inconsistency in comparison to geometry of competing products with low variance. Examples of such distinctiveness in results from the case study can be seen in:

- Distinctiveness from the competition in the relative vertical badge position and grille shape.
- The distinct LSIC of BMW which varies when compared to those seen in competition.
- Shape plots show specific sections of the headlight outline/contour used to vary headlight shape across their range.

As with observations on consistency and evolutionary trends, data on distinctiveness can be used to form datums against which further designs may be judged.

It should be noted that it is not the intention of the aforementioned datums to explicitly direct judgement but provide deeper and more objective knowledge with which to rationalise on future styling decisions. Thus a further aspect of the support supplied by the method is in being able to reveal/advise possible strategies.

Objectively representing particular trends can alert designers to areas of appearance which can be strategically altered/promoted in order to fulfil styling strategy. An example of such a strategy demonstrated through the results relates to assessment of the headlight across the competition. It is seen that the BMW headlight shape is particularly similar to all of the direct competitors. Thus should BMW wish to become more distinctive from their competition they may choose to implement a step change in shape.

Another example could be to maintain greater consistency in LSIC appearance to attempt to foster a more significant reference to the brand through this feature. Thus returning to the concept of the ‘datum’, the data generated through applying the method can be used to plot such strategies and hence objectively evaluate future designs with respect to these approaches.

11.6 Concluding remarks

This chapter uses a case study to apply the overall method to measure and compare product appearance to demonstrate its use in supporting designers during the styling process. Hence the method was applied to a number of vehicles from a number of contexts. These include vehicles from the current BMW range, previous generations of the BMW 3 series and 7 series, and a number of vehicles said to in competition both with the BMW brand as well as individual models.

Following the application of analyses, the degree of similarity calculations were interpreted to show a number of trends in terms of consistency, evolution, and distinctiveness in appearance with respect to feature geometry. Trends identified include consistencies in feature shapes across the current BMW range. Evolutionary

trends are demonstrated in the relationship between grille and headlight geometry. Areas of distinctiveness are shown relating to the grille and high variation in the LSIC geometry across the BMW range.

The quantitative identification and representation of such trends is shown to provide insights to support the styling process in that they can be used to form numerical 'datums'. These may be used to evaluate novel designs and subsequently be able to reason and communicate on appearance objectively. Such representation of trends may also be used to advise possible styling strategies and create subsequent 'datums' against which to assess the suitability of novel designs with respect to said strategies.

12 CONCLUSIONS & FURTHER WORK

This thesis presents research with the overall aim of creating a method to measure and compare appearance. The need for the research reported in this thesis is defined from literature of the related topics. Survey of the literature on design processes ranging from generic product design and development to vehicle styling processes, highlights the role of evaluation in driving the creation and development of designs and thus the eventual appearance of products. Also highlighted from literature concerning the styling process is the subjectivity and thus difficulty in evaluating the aesthetic properties of appearance in comparison to more objective factors such as materials, manufacturing, cost or aerodynamics. Furthermore, from the literature on approaches to improve the styling design process, it is seen that there is a gap in research attempting to address this issue of subjectivity in evaluation of appearance.

The second major topic of literature reviewed in this thesis relates to factors that influence product appearance. Within this topic, there have been a number of approaches that rationalize the different reactions that appearance elicits from consumers. While these approaches are valuable to designers, they address the emotional character of forms and as a consequence are relatively subjective. A notable exception is in the relationship between appearance and product branding which results in far less subjective insights.

Review of the strategic use of appearance demonstrates a further set of factors that influence the eventual appearance of products. These factors are shown to be multifaceted and complex to evaluate with respect to appearance. It is however also noted that despite the complexity they may all be considered in terms of relative similarity and difference. Thus, the consideration of appearance with respect to brand and the relative similarity of products are highlighted as two areas that form the focus of this research, and lead to the need to reduce subjectivity in the evaluation of appearance and create a method to measure and compare product appearance.

To meet these needs a method to measure and compare product appearance has been created. Through a scoping study and case studies the method has been applied and the results used to demonstrate its ability to provide insights to support the styling process. It is further concluded that these insights give a novel perspective to review and evaluate appearance and thus rationalise decisions relating to appearance of future designs. This overall conclusion is now broken down with respect to each of the research questions answered in order to reach this conclusion. These are now discussed individually with respect to the research conducted during the course of the thesis and how they have been answered.

12.1 Research Question 1: How does the geometry that defines product appearance relate to visual branding?

To address this research question two objectives (I and II section 1.6) were proposed outlining the creation of a systematic method to isolate geometry and its application to investigate the relationship between geometry and branding. To answer these objectives the visual decomposition approach was proposed. This consists of three stages, creating/collecting the visual material that forms the basis for investigation, tracing the outlines of features and the possible need to categorise features prior to making comparisons across a number of products.

In order to complete objective II and thus answer RQ1 this approach was applied to a range of vehicles and decomposed features shown to respondents in a web survey. Thus the application provides insights into the relationship between geometry and visual branding. Namely that different combinations of features shown to respondents have different potency in representing/communicating product brand. Thus it is concluded that it is not the sum of features shown to respondents but the presence of particular features that most influences the recognition of brand. In the vehicles studied, it was shown that the 'Graphics' features were particularly indicative of vehicle brand.

There is a further, and perhaps more important, conclusion taken from the application of the visual decomposition approach. This is that the approach was successful in

exploring the relationship between feature geometry and appearance, and thus forms the basis for further research into objectively measuring and comparing appearance.

12.2 Research question 2: How can feature geometry be used to objectively measure and compare product appearance?

In order to answer this research question two objectives (III and IV section 1.6) were proposed to develop an approach to measure and characterize appearance and create software to apply the approach. Thus a software tool was created that facilitated the application of geometric measures to the traced features produced as part of the visual decomposition approach. In creating this software a number of limitations associated with tracing of features were highlighted and subsequently guidelines were created for the further use of the software in conjunction with the generation of visual material within the visual decomposition approach. These related to the need for relatively high resolution images (approx. 1500x200 pixels and upwards) created in standardized elevations of products.

Early experimentation with the software also outlined the need to develop analyses that investigate features more holistically, that is to say in consideration of their spatial/geometric interrelationships. It was also shown that there is a need to consider analyses which could account for shape as well as position and proportions seen in previous research/literature to investigate appearance.

To address the need and answer to RQ2 a set of analyses to measure geometry for the purpose of evaluating appearance were created. These are: a feature proportion analysis to measure proportional relationships between features: a feature orientation analysis to measure the relative position of features: and a feature shape analysis to review the outline/contour of features. Alongside these analyses of appearance, a method to apply them and calculate the degree of similarity was also proposed to compare respective measurements of products' appearance.

12.3 Research question 3: How can the proposed approach be used to provide insights to support the styling process?

Two case studies using smartphones and vehicles as their focus are reported to demonstrate the use of analyses and assessment of degree of similarity and also to explore how their application provides support to designers.

Results from the application of the method to measure similarity in appearance in the first case study (smartphones) was used to make a number of conclusions on the nature of similarity in the smartphones' appearance. This gives one example of the support that may be provided to designers as the smartphones are the subject of litigation surrounding their appearance. Thus objective findings concerning similarity provides explicit details of similarities and the degree to which they are similar, giving valuable and objective insights in the eventual decision relating to the litigation

It is noted that the scope of the first case study is somewhat limited in being able to demonstrate the method and compare appearance in a boarder range of scenarios. Hence the second case study includes a greater number of products and further interpretation of degree of similarity to provide more wide ranging support to designers.

Further interpretation is based on exploring the context of products and proposing the comparisons of most use to designers in different strategic uses of appearance. Thus the final stage in drawing together the overall method to measure and compare product appearance uses the degree of similarity calculations to highlight consistency, evolutionary trends and distinctiveness in appearance.

The quantitative identification and representation of such trends is shown to support designers in that they can be used to form numerical 'datums'. These may be used to evaluate novel designs and subsequently be able to reason and communicate on appearance objectively. Such representation of trends may also be used to advise possible styling strategies and create subsequent 'datums' against which to assess the suitability of novel designs with respect to said strategies. Thus in reference to RQ3, it is concluded that the through applying the overall method it is demonstrated how the

method may be used to provide support to designers and generate insights to support the styling process.

12.4 Concluding remarks

Following the creation of a method to measure and compare product appearance and its demonstration, a number of conclusions can be drawn on its potential to provide insights to support the styling design process.

The first mode in which the method is shown to contribute to the improvement of the vehicle styling design process is in the formalization of implicit knowledge. As shown in the need for this research, designers currently evaluate designs based on previous experience and intuition that includes the consideration/comparison of appearance to other products/vehicles. Thus comparison and considerations relating to comparison are implicit in thought processes/rationale and are not easily communicated to other stakeholders in the design process. The proposed method has been shown to make the same type of comparisons but in an objective or explicit manner and thus rationale is far more easily communicated in the form of plots/graphs and quantitative values.

The implication of improved communication between stakeholders forms the second key conclusion. Improved communication relating to the evaluation of styling facilitates a more efficient styling design process in that less time is taken in demonstrating and arguing the different ‘strengths’ of aesthetic properties in appearance relative to strategic use of appearance. This is because strengths can be objectively shown in a form that is comparable to that of costing or manufacturing considerations.

Furthermore, it is concluded that communicating such ‘strengths’ more easily can improve the quality and impact of designs. This is because better access to objective insights provides an increased knowledge of the potential influence of appearance on consumers. This in turn leads to a reduced reliance on conservative designs and greater potential for designs to be more revolutionary or interesting when produced with reduced risk of alienating potential consumers.

The final conclusion drawn on the contribution of the method to the styling design process is in the nature of its application. Support delivered to designers through the use of the method does not replace activities currently engaged in nor does it alter any of the current design activities currently used. A number of attempts in the literature to improve the styling process are discussed in chapter 3. Of these there is little evidence of improvements in the form of new types of process or activity (e.g. digital tape drawing, direct sketching in 3D environments) being taken up by industry. It is contended that one of the reasons for this is the requirement for designers to change their practice and relearn skills, acknowledged as being a barrier to new activities/techniques introduction and use.

Thus it is concluded that the proposed method is particularly valuable in that it provides improvement without disrupting current preferred design activities. Moreover it uses the output material from the current design processes (images of vehicles) as the base visual material on which the method is applied. In other words, the method is supplementary to the design process rather than alternative to any steps.

12.5 Limitations

The first limitation raised is in relation to the research methodology adopted to create the method to measure and compare appearance. As discussed in chapter 2 a sequential mixed methods approach is adopted, however as also discussed there is a limitation in the extent to which the proposed method is tested and validated. As such there is a limitation to the degree of authority that can be given to validation of the proposed method. In other words the method has been demonstrated theoretically through case studies however it would require use by practicing designers to evaluate the usefulness of the insights generated.

As discussed in the development of the visual decomposition approach in chapter 5, the first major limitation in the method is the use of 2D images as base for investigation of appearance. This forms a limitation in that it is an inherent abstraction from the geometry that embodies features in product appearance and as a consequence requires geometry to be interpreted by tracing feature outlines. The implication of this

is that there will always be some subjectivity in defining features and hence a degree of inaccuracy in the features which are measured and compared.

Notwithstanding the above, it has also been shown that there are some advantages to the use of images in the ability to quickly and easily compare products without access to the products themselves or 3D surface data. Furthermore inaccuracies are accounted for and minimized in the overall method presented.

This being said, there are also significant advantages to using 3D surfaces data as a basis for applying measures in that a higher level of accuracy is maintained. The downside of doing so is in access to or resources to create said surface data also as previously discussed. Thus limitations in the base material used in the method are managed depending on the resources available to access surface modelling files, recreate models, or scan the surface of products to be investigated.

Further to the limitations of base material is the concentration of the method on feature geometry. It is acknowledged that geometry only makes up part of product appearance. Colour, surface finish, material and texture are all significant aspects of appearance and should not be neglected. Indeed some of these aspects form important visual references to brand in their own right.

There are also limitations to the method in terms of the types of products which can be assessed as previously discussed in section 8.3.4. There is a requirement for the products investigated to have a base level of similarity for the resulting measures and comparisons to be reliable. While it is demonstrated that the method is still valid despite this it is nevertheless a limitation in that there are instances in which the current method is not applicable but would be of use. For example where a company produces a large range of product types but wishes to maintain continuity where possible in appearance. Another example where the method would be of use but is not immediately applicable is in the design of highly novel or paradigm shifting products where a brand aesthetic is to be perpetuated.

As discussed in at the end of chapter 9 there is also a limitation in the definition of what constitutes a brand aesthetic. In degree of similarity calculations in relation to a range of products the number of products and the relative disparity in their appearance can significantly affect what is calculated to be similar or dissimilar. As a result any

judgment on what is included in a brand's 'aesthetic' requires further review by the designer of the context of features. The method is only capable of highlighting similarities and consistencies in appearance, not proving explicitly whether these embody a brand aesthetic.

The final limitation in the use of the proposed method is in reference to its contribution to evaluation as a step in the design process. The result from the application of the method is in objective/numerical information on similarity. This is not enough information in itself to make informed judgments on appearance. The method still requires an 'experienced eye' to make important decisions. The method is only intended as a tool to communicate the rationale behind such decisions and highlight/present opportunities in strategic styling.

12.6 Further work

From the conclusions further work is now considered. This is done in three sections, immediate further work relating to further validation and testing of the proposed method, intermediate further work relating to the improvement of the approach and long term further work relating to the potential future uses and applications of the method.

12.6.1 Immediate further work

As raised in 12.5 there is a limitation relating to the degree to which the proposed method is tested and thus validated. As such immediate further work is expected to focus on the implementation of the proposed method in industrial cases. Doing so is expected to give further feedback on the proposed method and highlight opportunities for improvement. It may also highlight any shortcomings and or potential improvements that arise from extending the application of the method to another mass-market product category. Of particular interest are those in which product brand is less obviously communicated through form such as white goods.

12.6.2 Intermediate further work

The first aspect of further work proposed relates to the potential use of 3D surface data as a basis for researching feature geometry. In order to apply the method to such data there is a need to further develop the analyses proposed. This means adding a further dimension in proportion analysis to consider volume, surface area and depth along with proportions currently assessed. Orientation analysis would need to consider the Z-axis in order to plot position in 3 dimensional space. Finally for shape analysis a regularly distributed array of points would have to be plotted over the outer surface of features and the radial length from points to the centroid of the surface area /centre of gravity calculated. The corresponding plots resulting from analysis would remain relatively unchanged. The only difference would be in the need to present shape analysis as a surface plot.

The use of 3D surface data presents an opportunity to create a generic criteria to define the boundary of features based on their geometric properties. Readily available geometry from surface data means that generic rules can be generated to provide a geometric definition of feature boundaries. Subsequently the same definitions can be applied less subjectively and be repeated for a wide range of feature types and also product types. It is however acknowledged that, while the creation of geometric rules to define features can reduce subjectivity, there still remains a degree of subjectivity in the derivation of these generic rules.

Referring to the limitation of the method in the requirement for a base level of similarity between products, further work has been undertaken to explore methods to compare more disparate forms. This took the form of using Fourier decomposition to model feature shape and then compare respective Fourier coefficients to assess similarity. The advantage of doing so automatically removes contextual factors of scale and rotation and hence allows for the comparison and judgment of similarity of any form. Details of this further work are published in Ranscombe et al. (2012).

The final element of immediate further work relates to further interpretation of degree of similarity and comparisons made to support designers. The method currently provides guidelines for comparisons thought to be of particular use to designers and are demonstrated in case study 2. While these are expected to be of most use in the majority of design scenarios, it is thought that there may be situations in which other

comparisons should also be considered. Hence a strand of further work would be to investigate different design situations that are faced by designers and review that interpretations/comparisons of degree of similarity that would be of most use. This is particularly important given the increased quantity of data that would be produced with the possible use of 3D surface data and thus there is an increased need to understand which data is most useful for a given situation.

12.6.3 Long term further work

One of the most immediate further applications of the method is its integration within industry standard design software. It is envisioned that geometric data inherent in surfacing software and in conjunction with datums could be used to create analysis tools similar to ‘zebra-stripes’, ‘curvature combs’ and ‘hotspot’ used in Alias software developed by Autodesk which allow designers to review surface properties quickly during design.

It is thought that the method could be further extended to provide measurement and comparisons of aspects of appearance not currently included in analysis such as colour, surface finish and texture. In these instances degree of similarity could be calculated using colour indices such as Pantone or CMYK codes, or measures for surface roughness to compare similarities. Given this data it is proposed that the same principle for calculating degree of similarity could be applied, and thus objective evaluations made that include almost all aspects of appearance.

Another application of the method is in using the resulting geometric data to automatically generate subtle design alternatives based on datums. While this is similar in concept to previous research such as shape grammars there are two crucial differences. The first is that this would be used to promote a range of possible concepts, rather than create an ideal or finalised design. In doing so man-hours could be saved that would otherwise be spent on surface modellers generating such alternatives manually. The second difference is that there is the potential to create alternatives within design software based on designs already manually created, differing from other approaches that generate designs from scratch.

The final further application of the method is in using geometric data and datums to create a tool to search for similar geometric forms. Thus a novel design can be the

input to search a catalogue of forms to highlight any particular similarities. Additionally a particular form or style may be searched for examples and the style emulated. Such a catalogue is thought to have particular implications for the management and defence of registered design.

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APPENDIX 1: INTERVIEWS WITH DESIGNERS

This appendix provides summaries of the information gained from discussions with designers from the automotive industry and in academia that have taken place over the course of this research.

Industrial visit to GM Holden

Interviews conducted by Dr Ben Hicks with Richard Ferlazzo — Chief Designer and Sharon Gauci — Chief Designer Colour and Trim.

Interviews took place as part of a visit to GM Holden Design Studio, Port Melbourne, Melbourne, Australia during August 2006. The results of the interviews provide a detailed example of the vehicle design and development process and steps followed.

Holden employs approx. 8,000 people. The design department has 170 people only 25 of which are designers. Other roles are in: Administration, Creative, Studio Engineering, Clay Modelling, Digital Modelling, Colour & Trim, Perceptual Quality, Visualisation, Business & IT, Human resources. New vehicle introduction is a seven-year program requiring over \$1 billion US dollars of investment. The following is a timeline for its development.

Exterior design process — Timeline

1999 (Early)

1. Occupant configuration, power train, wheel/axle dimensions and door opening profile are determined
2. Architectural layout determined. This includes engine and suspension, occupant zone and rear (boot).
3. More than seven variants for niche markets (7-8,000) are produced. This includes a Sedan, Coupe, UT, Estate, Pickup, extended sedan, Statesman and others.
4. In order to deliver this variety Holden employ a flexible architecture for the chassis. This includes two slip planes. One between engine and occupant zone and one between occupant zone and rear. This allows a large variation in the wheel base.
5. Program framing for development — timelines etc.

2000 (Early)

6. Concept sketching — six months where designers can let their imaginations run wild.

2000 (Mid)

7. Eight scale themes developed (30% scale). These are half models from clay set against a mirrored wall.

2001 (Early – mid)

8. Scale models are reviewed. Four themes progress to full scale. Two will be the 'best' or preferred and two will be 'reach' models. Because it is a seven year programme the reach models are slightly more futuristic in terms of styling and might be more appropriate in a couple of years.

2001 (End)

9. Full scale model review outdoors. Models are painted etc. (Colour & Trim is developed in parallel)

2002 (Early)

10. Two themes are selected for model refinement. This involves manufacturing engineers etc. — can we make this?

2002 (Mid)

11. Engineering produce one-offhand built vehicles. One theme selected.

12. Clay model is scanned. Then model is further refined through a parallel process of clay modelling and surface modelling. In particular, the surface modelling uses lighting effects to evaluate the surface — harmony, tautness, lines etc. The modelling package used is called 'Alias' and is used by most manufacturers.

2002 (End)

13. Final refinement of front end styling.

2003 (May)

14. Full size development concludes.

15. Final scan and Alias modelling. Process takes about 8 weeks and will be the data from which components are manufactured.

16. Refine and check mathematical surfaces using various colour and lighting effects — e.g. Zebra stripes in red, black and white.

17. Verify surface model by milling a full size clay model from the data. The model is then foil wrapped to verify surface quality.

2003 (End)

18. Verified surface model is released to engineering.

19. Further validation through hand built model with see through upper (i.e. windows).

2004 (Early) - Manufacturing processes and detailed engineering work is undertaken. Production systems designed and specified Production In parallel to this the interior design and trim/colour are developed

2005 - Production systems specified

2006 - Production

Interior design process – Timeline

In parallel to this the exterior design and colour and trim are developed

2001 — 2004 Interior design

1. Initial math modelling of interior using CAD tools.
2. Clay model development.
3. Construct full size interior models for 8-10 designs. These are quarter bucks — Dash, seat and door. There is a need to sit in, touch and feel designs.
4. Final design agreed in 2004 but further refined in 2005-2006.

2001 — 2005 Trim and colour

1. Lots of research undertaken in the fashion industry and product design.
2. All vehicle colours are specifically designed for the range. Eight new colours are created. Colour design is a three-year process and runs parallel to the body design so that colours and models can be considered together.
3. Surface texture for dashboard etc. is important. The grains are actually designed. Holden has two new textures — technical and animal. They often look at nature for inspiration.
4. Decoration design involves lenses, badges, wheels, handles, aerials, grills etc. and begins once a full size model (design) has been selected (2003-2004). 5. Final area is soft trim design — upholstery etc., smell is important in Asia-Pacific markets and Middle East.

To assist in these processes the team construct a design for differentiation matrix (below) into which all models and variants are placed.

	COMFORT	SPORTS
FUNCTION		
PERFORMANCE		
LUXURY		

In addition to the above, the vehicle brochure is also designed before the first production car. The images in the brochure are not photos they are images taken from the Alias models!

Vehicle styling symposium Coventry University

The following sections summarise information gathered from 3 seminars and additional discussions with industry professionals at Coventry University on 4/6/2009.

Bones Muscles and Graphics

Seminar given by Nick Hull, Course director Transport design at Coventry University and associate editor of Car Design News Ltd. discussing the physical form in Car design and the design/styling process.

Bones

The first stage in the styling/conceptual design process is to define the volumes of the car. This looks into the overall form of vehicle and establishes elements such as the weightiness and stance of a vehicle. The idea of bones was compared to skeleton in the animal world, in other words it defines the overall shape of a vehicle. One analogy given when explaining the idea of a skeleton was to ask oneself whether a car's form resembled that of a leopard or a gazelle. It was also mentioned that stance is something European car manufacturers obsess over far more than other manufacturers.

The next stage is to work on the most prominent line shapes on the vehicle. These add a little more detail to the outer form and begin to give some further styling cues. For example, in the front and rear views, the tumble home and tuck under lines can be used to establish the sportiness of a car's appearance.

Muscles

Having defined the overall form or skeleton of a vehicle, the muscles make up the rest of the appearance. Continuing the anthropomorphic analogy, human skeletons are constructed of the same bone structure, but it is the muscles, skin and flesh that define a person's build. In the automotive world it is the vehicles surfaces which further define the 'build' of a car. Subtle variations or shaping of the surfaces of a car can define characteristics such as, soft hard masculine, feminine, organic, geometric, shear, crisp or voluptuous.

Graphics

The last stage in defining the emotion and character of a vehicle is to add graphics. These include adding lamps, DLO (day light opening or window) layout and importantly the front mask and grille.

Other points

- Importance of golden section, retrospectively rather than actively during the design process
- Convergent divergent pillar lines
- Anthropomorphising the front end to look like be a face. Too much resemblance detracts from the vehicle's legitimacy.

The Art of Facelifts

Seminar and subsequent interview with Steve Harper, Design director at SHADO car design consultancy, previously chief platform designer and concept designer at Volvo Sweden

Facelifting refers to the activity of car manufacturers changing aspects of a current model to increase its profit making life on the market. It is a very cost constrained exercise. This lecture gave significant insight into the constraints faced by designers and how they communicate with external departments and stakeholders on the design.

Premium brands facelift less often than other brands to maintain brand image or consistency.

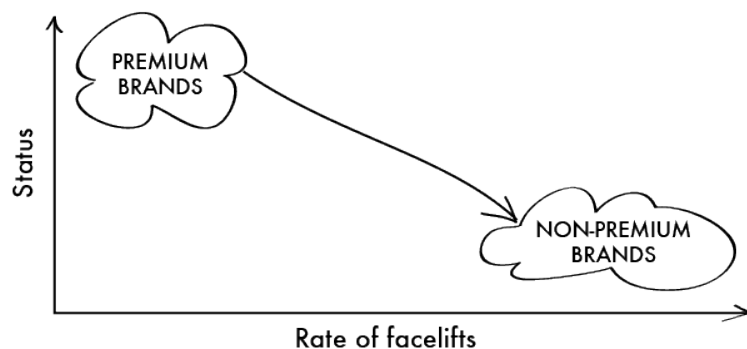


Illustration of the relationship between brand status and the frequency of facelifts

Designer – Constraint interface

Designers have to become aware of the general company financial situation and involve themselves in costing groups. A lot of the knowledge what will/will not be acceptable is made up in career experience or working with more experienced

designers. Awareness of the company forms a major part of being able judge and pitch designs.

Constraints on cost etc. come from within the car manufacturer but suppliers impose just as big a constraint if not more on designs. Example given: The manufacture of the new Volvo floating dashboard is outsourced. Hence to redesign this the designer must be aware of the suppliers limits in what they can manufacture as well as when they will be able to deliver.

Nissan Design Process: Designing the Nissan Qazana Show Car

Seminar given by Matt Weaver, Project leader at Nissan Design Europe

The aim of this seminar was to give an insight into the initial stages of the car design process. As not to give away any sensitive/confidential information, the car studied in this lecture was a show car. The Nissan Qazana was a show car used to give customers an insight into the style and character of what the actual production car will be. The process of developing the show car was very similar to that of a production vehicle apart from the timescale. This show car was designed to be released at the Geneva motor show, March 2009. The project conception was around May 2008. Average show car time from inception to completion is between 8 months to a year. Much of this depends on the type of concept being developed, blue sky or like the Qazana, more production realistic.

1. Receipt of the design package. Mood boards and a basic schematic detailing the wheel base and driver position. There must have been input from the design of the production version of the Qazana was, as the show car's aim was to give the public a taste of the production Qazana's design.
2. Inspiration hunting. Designers begin to look into imagery to form the basis of an aesthetic. Similar to all design. Nothing necessarily car related. In this Qazana example there was a lot inspiration gained from the film "Little Miss Sunshine" promotional material combined with an image of Elvis in a beach buggy.
3. Next ideas and aesthetics begin to be realized in sketch form
4. 1st iterative stages begin between Alias and hand sketches
5. New stage is added into the iterative process, Clay modelling



Nissan Qazana

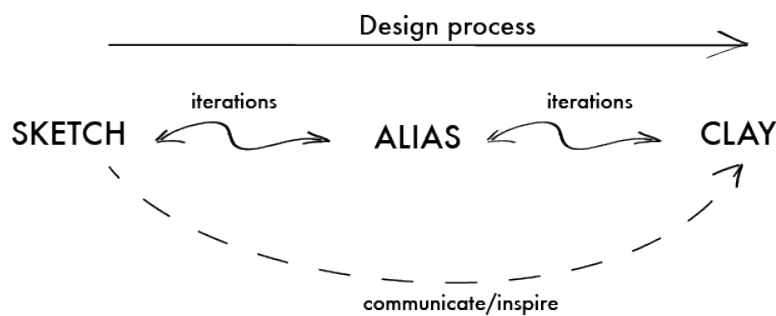


Illustration of styling design process adopted for Qazana development

6. A possible design was constructed in Alias and deemed to be suitable for clay modelling at one quarter scale. One production of the model the design was deemed unsuitable and a second total iteration was embarked upon.
7. The final design was developed on Alias. This development goes to the stage of a fully rendered model following a number of iterations. This model was deemed good enough to be physically modelled at full scale in clay. The clay model is used as a design tool rather than a representation of a design. Much time was spent with the full scale model finalizing surface design. It was made very apparent that 3d digital models were very important but the ability to walk around a full scale model could not be neglected or replaced.
8. While modelling with clay, Dinoc is stretched over the surface to give the model a metallic finish.
9. Tape drawings were not used in this case study how ever there was talk of using taping techniques on the clay model as a way of portraying important lines to the design managers and the clay sculptors.
10. Once the clay model has been fully finalised, 'Design Freeze' occurs. For the next step there are two options. In production cars the model will be scanned in

3d to be returned to digital format for further development and tooling. This can also be done when developing one off car designs. In this case study, the clay model was used as a basis to build a mold in turn used to build the concept's body panels in fiberglass.

Interview with Chris Pollard

Chris Pollard, Coventry University Transport Design graduate and previous employee of Land Rover. Chris provided his version of the styling process

1. Receive the design package. This is usually done as part of a team which split up into smaller groups or individuals. Design packages can vary a lot but usually come in the form of engineering constraints, imagery and vocabulary relating to the envisioned car's aesthetic.
2. Designers begin to build on the information given to them by hand-sketching to embody ideas quickly and cheaply.
3. Gradually enough ideas are put down on paper to allow designers to begin to visualize a 3d form. At this stage some initial models can be made in Alias. With the aid of hand sketching these models can be refined to the point where a presentable 3d model is constructed.
4. Formal concept review processes take place, The format described at land rover took the form of a side by side review. All concepts, up to five would be projected at full-scale on two walls. Usually the design managers will choose elements of the different concepts that are liked and disliked and from here move on to another divergent concept generation cycle.
5. Any number of these iterations may occur until a 3d digital concept is deemed suitable enough to be modelled in clay. In the case study of the Qazana a scaled down model was constructed, however this was thought to be somewhat out of the ordinary certainly from the point of view of the procedure at Land Rover. Usually Alias is relied upon to develop models to the point where they can be made at full scale. When asked outright about the use of tape drawing Chris made it clear that this was an old technique and at Land Rover designers went from hand sketching to Alias without constructing any drawings at full-scale. The use of projectors showing 3d digital models at full scale seemed to have superseded tape drawings.

The possible progression of the research and the nature in which the tool would support designers was also discussed. Chris was particularly adamant that any support must be developed from methods that designers use rather than attempting to make changes using approaches devised from an engineering or marketing sphere. Chris felt that such approaches would not be well received in industry as they would detract from the designers skill and creativity

Graham E. Pepall

The interview with Graham E Pepall took place on 18/8/2009 at the University of Bath. Graham is a retired designer with interest in the direction of the project. His experience includes working as a lead designer for Mazda on the first MX5 model as well as a manager at IAD (International automotive design), a global automotive design consultancy.

The discussion began by Graham running through the styling process. This was done using case studies of his works to illustrate different points. This guide was left with the University for further reference.

Following his explanation of the design process a validation of perceived models for the process gauged from literature was undertaken. It was quickly established that this depiction of the process was correct with the only criticism that communication between stylists and engineering designers begins as soon as possible.

Following this the thought/work process leading to the current view of the direction of the project was explained. A description of studies undertaken throughout the above mentioned process was made. This description was used to argue the desire to further investigate the stages prior to the production car styling and design process.

Points dwelled upon:

- The importance of hand sketching
- The use of tape drawing as a quick method of full scale sketching for management review
- The absolute need for a full scale model before a design can be signed off, and for much easier development of engineering aspects.
- The need for human judgement in sculpting surfaces.

The following questions were discussed. Answers are connected to the questions in the form of a discussion.

Pre design or advance design stages

- Who is involved with this stage? Can you summarize the steps? – This is predominantly the undertaking of the product planning dept. they consist of marketing, manufacture planning, cost engineering, design and strategy. Just about everything that is needed to plan the production and sale of a car. Other important departments at this stage are the advance design department who deal with design of advanced vehicles. They take inspiration and design topics from the outcome of the product planning process. These departments are independent in terms of task, this is what they do 100% of the time.

- Is it possible to define the use or purpose of the different levels of concepts presented by a company? – Concepts can be split into three categories; advertising and showcasing the company, show cars relating to a potential production car, concepts used in the decision making process when designing production cars.

Graham then talked about his involvement in developing the Mazda MX5. The description of this process was very similar to that described by Matt Weaver of Nissan Design Europe when describing the Qazana show car. Similarities in that these were vehicles designed and developed to gain public opinion of the concept. The brief was passed to the designers from product planning department as a short project, not aimed for immediate manufacture. Graham related another example of the use of these types of concepts for eventual production car in the latest Honda civic.

- Your opinion of previous use of shape grammars in automotive design? It has no use in the stages that are mostly occupied by sketching out parts of ideas to eventually focus on a concept of a full design. This approach would alienate designers. You must support/communicate with designers in a form that is familiar and in which they are skilled.

Other points: Management in the design industry, particular automotive, are aware of the necessary investment and the associated risks. Hence final judgments are often hotly contested. Graham had a particularly positive reaction to a decision making aid as a way of providing further insight when making decisions.

Peter Elliott

Interview conducted with Peter Elliot at Monash University Faculty of Art and Design on 8/8/2011. Pete currently works as a senior designer and supervisor at Ford Australia, Lead designer at Volgren Australia (bus manufacturer) and has a role lecturing in transportation design at Monash University. Peter has been involved in a wide range of projects over his career. Of note was his role as lead designer for the entirety of the Ford Ranger project, a major ground-up design exercise for a vehicle sold globally. Peter is currently engaged as the lead designer for the new Mondeo platform.

Comments on models for the styling process

Broadly the model (Figure 18) is correct however complexities mean that it is particularly hard to create an in depth model applicable to all cases/projects

Further questioning about the types of complexities highlighted three areas of complexities, the product, people working on it, and the organization within which the project is undertaken.

Product

Product related complexities are associated with the type of vehicle being designed. There are a range of vehicle types that form the focus of a project such as; a complete 'ground-up' design for a totally new vehicle. A vehicle re-design part way through its

life cycle such as a ‘mid-cycle’ refresh or ‘facelift’. The project could be a ‘Show car’ or ‘futuring concepts’. Each of these types of project will inform the nature of the process used by designers and others involved with the project.

People

People related complexities are driven by the people within the vehicle/products target market and are thus associated with the personnel brought in to work on the project. As an example a new vehicle for the global market will likely incorporate a lot more company personnel from different offices across the globe. A niche product aimed at a particular region in a particular market will incorporate less and more localized personnel. Additionally in the presence of platform sharing across different brands, personnel from different brands designing different vehicles may have input if parts are to be shared. Finally new management in departments can influence the people involved in the design process and thus provide further complexities

Manufacturer/Organization/Brand

The brand or company environment in which a vehicle is being designed can greatly influence the design process. Factors such as the brand history or heritage have an effect along with current situation of the product range and previous products offered. Furthermore the capacity of manufacturers to produce more or less of particular parts can affect the process of design. All of the above aspects from the three complexities inform the bulk of the details of the design development process.

Such vast projects mean that good team working is absolutely essential. Lead designer does not translate to the only designer. With said teamwork there is a need to understand and communicate the styling strategy and concepts with the styling group and with involved parties in marketing and engineering.

Discussion of evaluation of designs

Meetings between the designers and design managers take place informally on a daily basis. A design group as a whole usually meet to discuss designs on a weekly basis. Discussion with personnel from engineering design and or marketing can vary greatly depending on the nature and phase of the project and the people involved. The nature of meetings also varies from informal talks to presentation and formal discussion.

Often at some stage of the design process there is some form of ‘Face-off’, in which designers and engineering or marketing personnel (usually engineers) disagree over some aspect of the design. This is often driven by compromise between possible savings made by changing some aspects of styling. Peter eluded that this was an inevitable aspect of the design process due to the level of investment at stake. From experience Peter found that the time spent debating such matters and degree of ‘bad feeling’ was dependent on the ability to communicate and empathize between stakeholders.

Mark Richardson

Interview conducted with Mark Richardson at Monash University Faculty of Art and Design 10/8/11. Mark is a senior lecturer in the Transportation design course at Monash University. His previous industrial experience was at Ford Australia where he worked as a senior designer for over 10 years.

Comments on models for the styling process

Mark largely concurred with the model of the product and vehicle design development processes. The broad step and flow of activities were deemed correct however the overlap and iterations between departments was under emphasized.

Rarely is vehicle design development process as simple as passing the design from one department to another. Often personnel from all departments are involved concurrently

Interaction and communication between stakeholders.

Often one of the main difficulties in the design development process is derived from the subtly different agendas of the different departments stakeholders. Although all personnel are aiming to produce the most successful product, marketing are aiming to produce the most successful in terms of popularity and thus sales, manufacturing are aim to produce the most inexpensively made successful design and design teams are attempting to manifest these factors in terms of a physical form.

As a consequence of the subtly differing agendas, there is a difference in the vernacular and methods of justification of the different departments. The interviewee stated that, in his experience, one of the hardest aspects for the designer is to justify designs to different departments. Mark then eluded to the fact that one of the reasons for the difficulty in justification was potentially due to designer's inability to justify designs in as objective terms as marketing and engineering design departments. These personnel usually work in terms of numerical justification whether through consumer research or manufacturing data/costing. Evaluation of designs is far more subjective hence designers may find it difficult to justify aspects of styling when faced with more objective argument.

In summary Mark concluded that much of the design process in the large organisations is dependent on diplomacy between personnel within teams and between teams. Much of successful diplomacy and compromise is down to lines and modes of communication between teams, and an understanding of the different challenges and agendas faced by different teams.

Ilya Fridman

Interview conducted with Ilya Fridman at Monash University Faculty of Art and Design 15/8/11. Ilya has experience in Industrial design generally as well as two years experience as a surface modeller at the GM Holden design studio. His current role is as

a lecturer in industrial design at Monash University while also undertaking a PhD in transportation design.

A discussion was conducted to probe the different terminology used in automotive design and in particular in discussion and evaluation of designs. The following terms were outlined and defined.

Terms

Lines - The term line is used as default term to describe curves of large radius. Lines are often manifested in intricacies of surfacing (raised or depressed sections) as well as the small gaps between panels and the profile of a vehicle. Thus often much of discussion of appearance involves the discussion of lines.

Corners - Corners are usually less in the spotlight for designers. They are almost a necessary evil in that they describe the section of a profile or panel that join lines.

Sweeps - A sweep is somewhere between a line and corner in that they use a larger radius than a line but smaller than a corner.

Cores - The core refers to the section of line sweep or corner where the curvature reaches its peak. When exploring designs lines are often modified by moving cores or adding cores.

Tension - Tension is a term used when discussing the intricacies of lines. It is used in reference to the curvature and change in curvature along and at the ends of the line.

Acceleration - Similar to tension, acceleration is used in the discussion of curvature and rate of change of curvature at the ends of lines and or through corners.

Evaluation tools in software

Ilya was asked about his experience of the use of industry standard surface modelling software during vehicle styling. Ilya made reference to a number of evaluation tools incorporated into the software to assist designers in the review of appearance. The tools are now summarized

Zebra Stripes – Projecting black and white stripes onto a surface of models. This is done to inspect nuances in surfaces and surface features such as character lines.

Curvature combs – Plotting relative values for curvature as lines (teeth) perpendicular to a curve being designed/modified.

Curvature surface – Representing curvature on a surface as a colour to assess any irregularities in curvature (hot spots).

Of note, curvature combs and curvature surface offer a quantitative evaluation of appearance

Constraints with respect to features during design

The last topic of discussion was in the nature of physical constraints on the form/geometry of graphic features. Insights were gained into the constrictions on the headlamp ‘package’ due to lighting technology adopted and the space required for the engine. It was noted that many of these constraints do not significantly impact the outline of the headlight and that much of the outline design is ‘cosmetic’, particularly in the extrema. Hence constraints relate purely to the change in tooling rather than feasibility due to technology or components.

Badge design was discussed with Ilya indicating that this was an activity not associated with the overall vehicle styling process. Moreover its design is usually defined during organizational (re)branding exercises.

Concluding remarks

Key conclusions drawn from interviews and discussions are now summarized. The first major conclusion drawn is that the styling process can differ greatly from one project to another. Differences occur in the time taken, level of involvement from different stakeholders and the number of iterations between stages. Some elements of the process are common across almost all projects. These are namely the steps/activities followed which begin with sketching ideas, moving to the use of Alias to create 3D surface models and eventually making clay models. Also common across all projects is the requirement for designers to interface with both marketing and engineering departments during the design process.

The second key conclusion relates to the role of the designer in the styling process. From interviews and discussion it is shown that while the designer’s chief focus is in aesthetics and borderline artistic, the underlying motivations are very commercial. Hence it is shown that the role of the designer is answering commercial motivations/demands using visual material. In doing this the designer is inherently involved in demonstrating the conversion of commercial requirements in visual forms.

The last significant finding from interviews was the effect of communication relating appearance to other stakeholders is essential in the design process and often a point of contention/friction between stakeholders. Hence the final conclusion is that a tool to assist with this aspect of the design process would be particularly valuable as it has the potential to expedite the styling process while supporting designers.

APPENDIX 2: FURTHER DATA FROM CASE STUDY 2

This appendix presents further data resulting from the application of analyses in the 2nd case study. Given the extensive nature of this study and the large volume of data collected, observations refer only to significant trends that are of potential use to the designer. Within each section results from applying the three sets of analyses are addressed individually.

Further results: current BMW portfolio

This section presents results and observations from investigation of the current BMW portfolio. Particular attention is paid to observations on consistencies in geometry.

Proportion analysis

Figure 110 shows the coefficient of variance in proportions between features across the current BMW portfolio. The figure is used to highlight the proportions between features that are most consistent across the current range.

From the proportion analysis data (Figure 110) it is observed that the greatest consistencies in proportions are seen between; the headlight and grille, the grille and CI, and the headlight and CI. It is also seen that the proportion in perimeter and width is consistent through all features compared with proportions in area and height.

Orientation analysis

Figure 111 shows the variance in orientation of features across the current BMW portfolio. The figure is used to highlight the position of key points in features that are most consistent across the current range.

From the orientation analysis it is first observed the CI centroid is most consistent. This is of little interest as this feature is assumed to be universally symmetrical about the vertical centre line. As with the proportion analysis, positions of the headlight and grille are more consistent than LSIC and CI features. This is particularly observable in the grille centroid and maxima, and the headlight Y components of centroid and minimum.

Shape analysis

Figure 112 shows two charts. The first shows the resulting shape plots from applying shape analysis to features across the current BMW portfolio. The second chart plots the coefficient of variance in shape for each of the features across the current BMW range.

From the charts it is possible to observe that there is a relatively greater consistency across the headlight and grille features compared with the LSIC and CI. Furthermore it can be observed that the variance along the contour of the grille is relatively stable while the headlight shows greater fluctuation in coefficient of variance. It is thought that this reflects the more simple outline of the grille versus the more complex outline of the headlight.

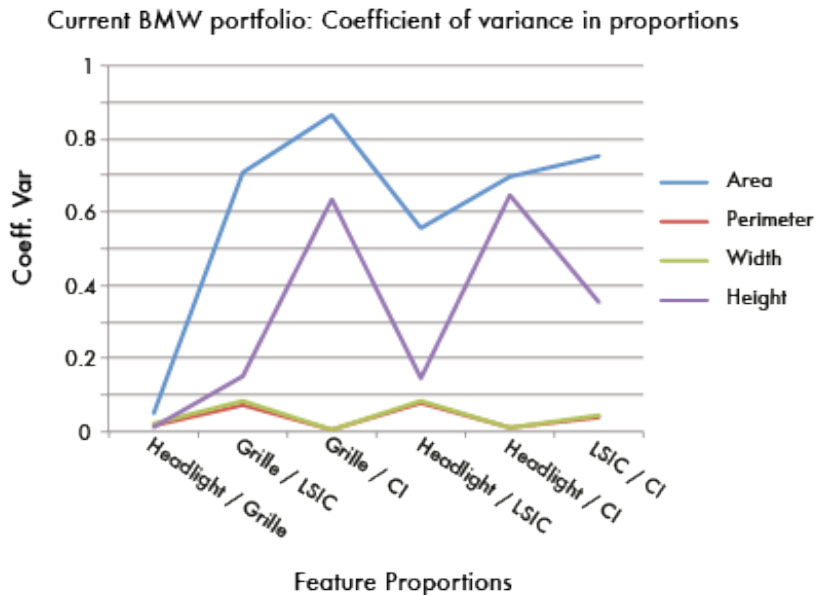


Figure 110 Plotting the coefficient of variance of proportion between features in area, perimeter height and width across vehicles in the current BMW portfolio

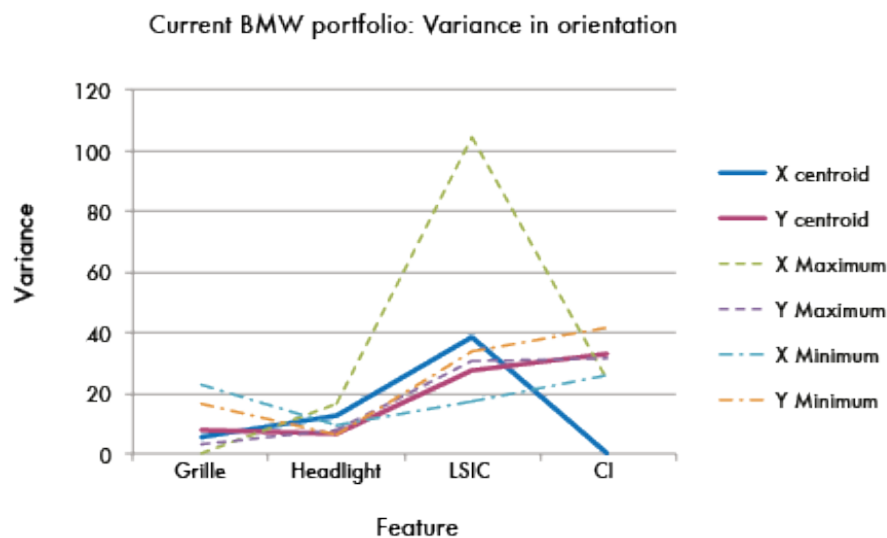


Figure 111 Plotting the variance in position of features centroid, maximum and minimum across vehicles in the current BMW portfolio

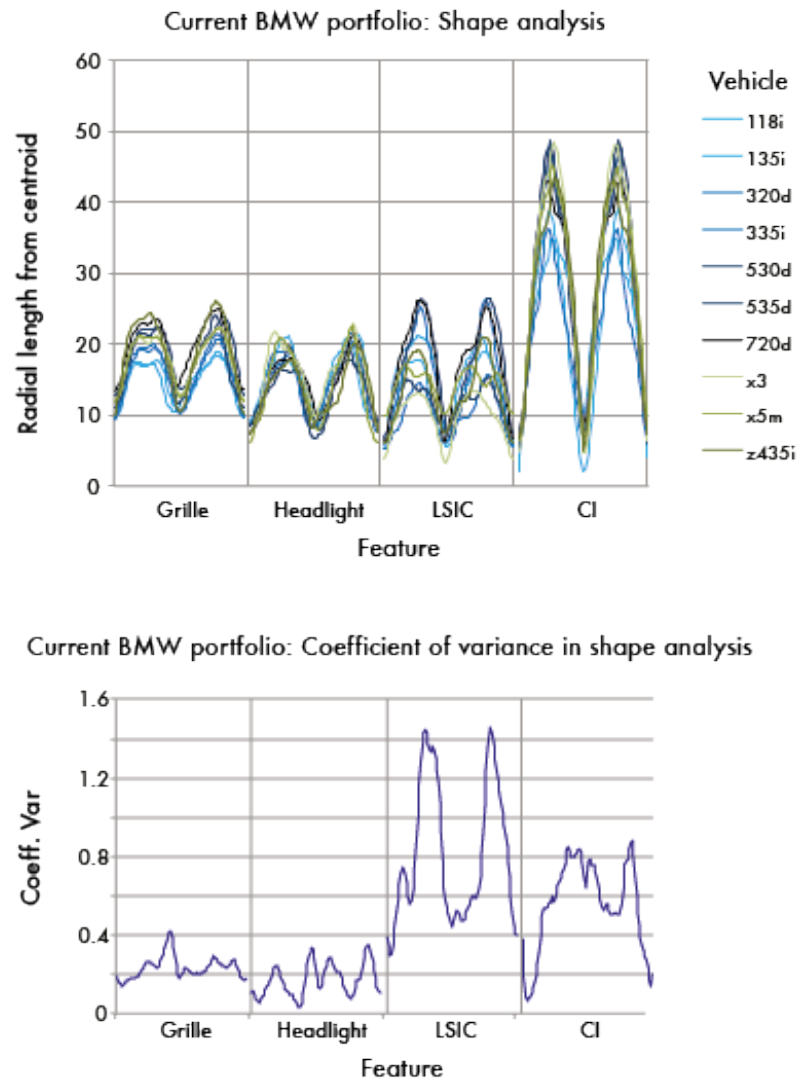


Figure 112 Charts showing the resulting shape plots from shape analysis and plotting the coefficient of variance in shape of features across the current BMW portfolio

Results: Previous 3 series and 7 series

This section presents results from the investigation of previous generation of the BMW 3 series and BMW 7 series models. Particular emphasis is placed on the observation of evolutionary trends in appearance.

Proportion analysis

In terms of evolutionary trends it is observed that there is an evolutionary trend in proportions between the grille and headlight features (Figure 113). The evolutionary pattern is exhibited in the proportions in area, perimeter, and width. The height proportion however shows a clear consistency through a low value for coefficient of variation (0.006 and 0.015 for 3 and 7 series respectively). No other significant evolutionary trends are observed in proportions between other features.

Figure 114 plots the coefficient of variance in proportions over previous models. From these plots it can be observed that consistency measured through values for coefficient of variance are approximately one order of magnitude larger than the proportions deemed most consistent in the current portfolio/range analysis (Figure 110). The exception to this is in the height of features across previous 7 series and headlight, grille and LSIC proportions in 3 series models. The coefficient of variance in height proportions range from 0.006 to 0.09.

Orientation analysis

From the orientation analysis it possible to observe that there is an evolutionary trend in the increasing distance of the grille centroid from the badge in the evolution of both 3 and 7 series models (Figure 115). The same is also true for the headlight centroid. This pattern is repeated in the maxima and minima (Figure 116 and Figure 117). The only exception is that the minima for the 7 series is constant. In addition it is observed that the X coordinate for the headlight minimum remains relatively consistent.

Similar to findings on consistency in the orientation of features in the current BMW portfolio (Figure 111) are observed for previous models. Results show consistency in the Y coordinate of the headlight centroid and both X and Y coordinates of the grille maximum. Respective values for variance are 2.9 for the headlight and 0.34 and 2.6 for the grille maximum.

Few significant trends or consistencies are observed relating to the orientation of LSIC and CI. The only major trend seen is in the relative consistency in the Y maxima in both the LSIC and CI for previous 7 series models (Figure 116)

Shape analysis

Observations of consistencies and trends in shape are now discussed in each of the features individually. In terms of the evolution of the grille shape it can be seen (Figure 118) that visually there is a step change in both 3 and 7 series after 1982 where grilles' width become greater than their height (also reflected in other analyses). A further trend can be seen in the increasing peak amplitude and change in gradient and skew of the first peak in shape plots. This relates to the gradual departure from more 'boxy' grille shape toward a more organic form. In subsequent models following the step change in grille shape, it can also be observed that the inner edge/half of the grille remains relatively consistent for both the 3 and 7 series. This is reflected in values for coefficient of variance (averaging 0.005 and 0.003 respectively)

For headlight shape it can be observed that there is an evolutionary trend for the first peak in the shape plot to decrease in amplitude over time. As with the grille shapes this reflects a trend toward more organic forms. This is the lower left corner tending more toward a sweep. This is most noticeable in the data for 7 series models.

Values for coefficient of variance show that headlights exhibit more varied but 'subtle' differences in overall shape. The grille adopts similar shapes with differences primarily in scale. This is seen when comparing the coefficient of variance plots for the grille and the headlight.

When observing data from the shape analysis of the LSIC it can be seen that the 3 series evolution shows the trend from rectangular forms to more organic forms.

There is a step change between the 2001 and 2006 where the forms become wider. With respect to consistency, values for coefficient of variance are high for both 3 and 7 series (3.45 and 2.68 respectively). This reflects overall inconsistency in this feature shape.

The evolution of the central intake (CI) for both 3 and 7 series shows little in terms of trends. There is neither a high degree of consistency (aside from the symmetry of the feature) nor is there any evolutionary pattern. Coefficient of variance is of a similar magnitude as that of the LSIC, 3.52 for the 3 series models and 2.63 for the 7 series models.

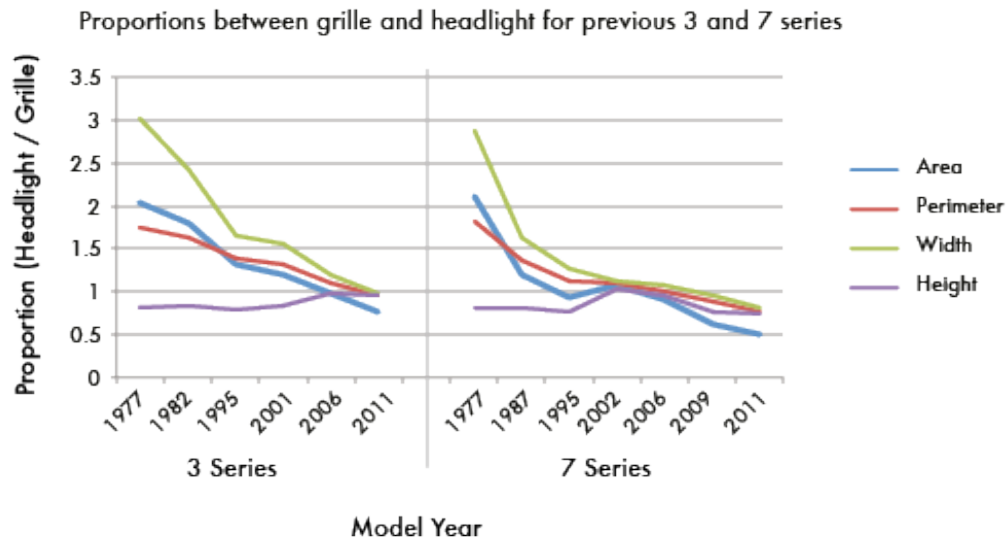
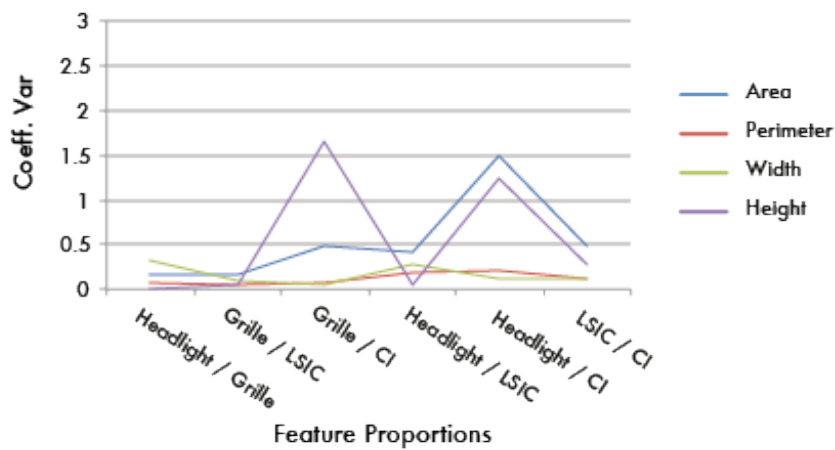


Figure 113 Plotting proportions between grille and headlight over previous models of BMW 3 series and 7 series

Previous BMW 3 Series: Coefficient of variance in proportions



Previous BMW 7 Series: Coefficient of variance in proportions

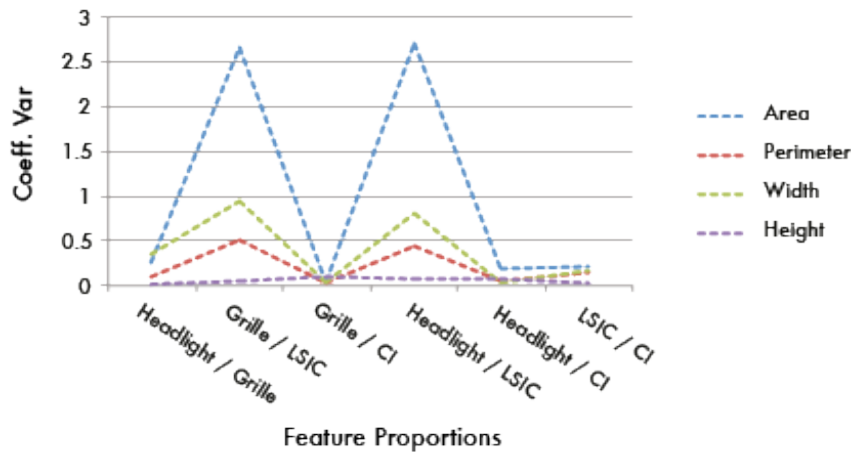


Figure 114 Plotting the coefficient of variance of proportion between features in area, perimeter height and width along previous BMW 3 series and 7 series

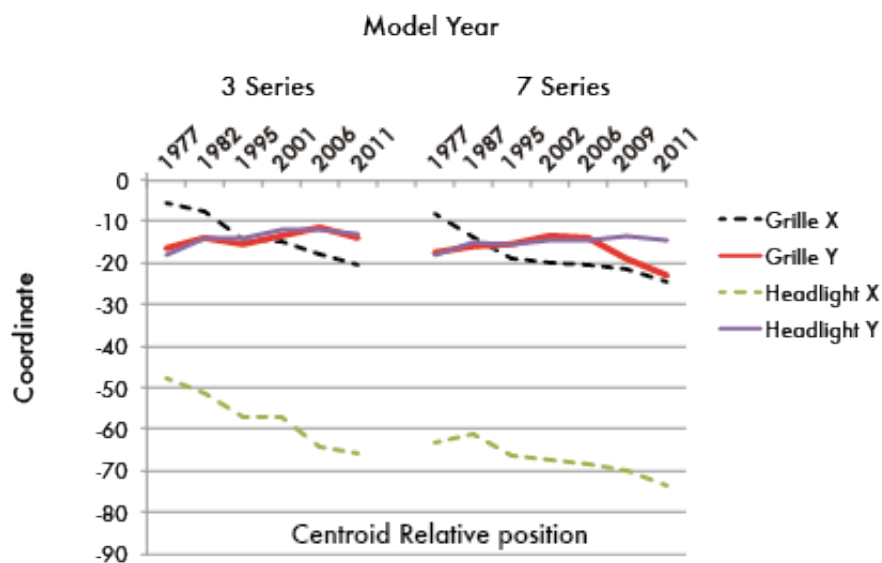


Figure 115 Plotting coordinate values for feature centroids over previous BMW 3 and 7 series

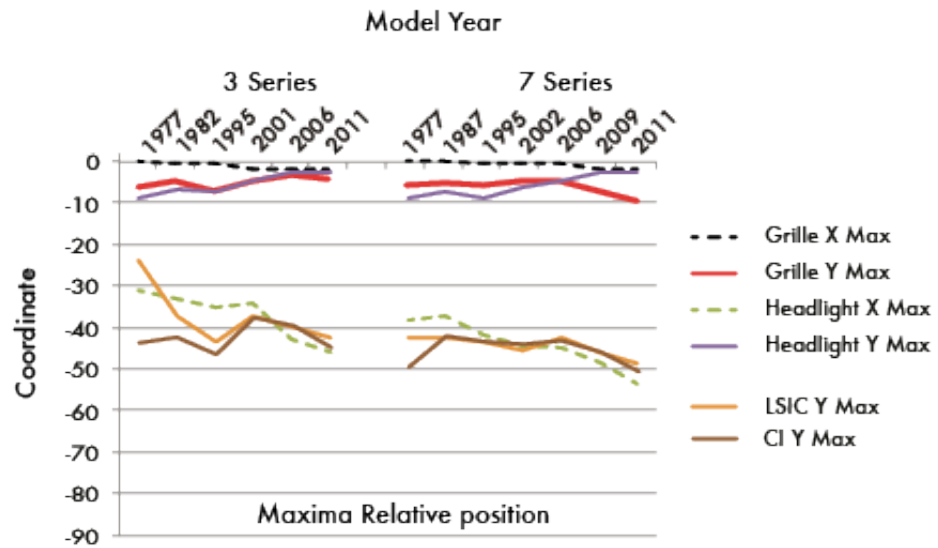


Figure 116 Plotting coordinate values for feature maxima over previous BMW 3 and 7 series

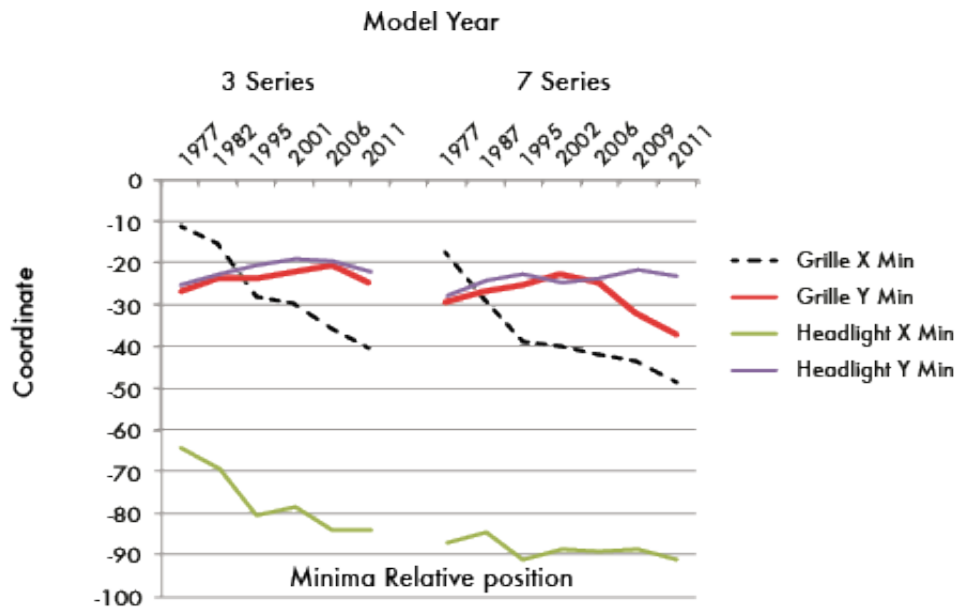


Figure 117 Plotting coordinate values for feature minima over previous BMW 3 and 7 series

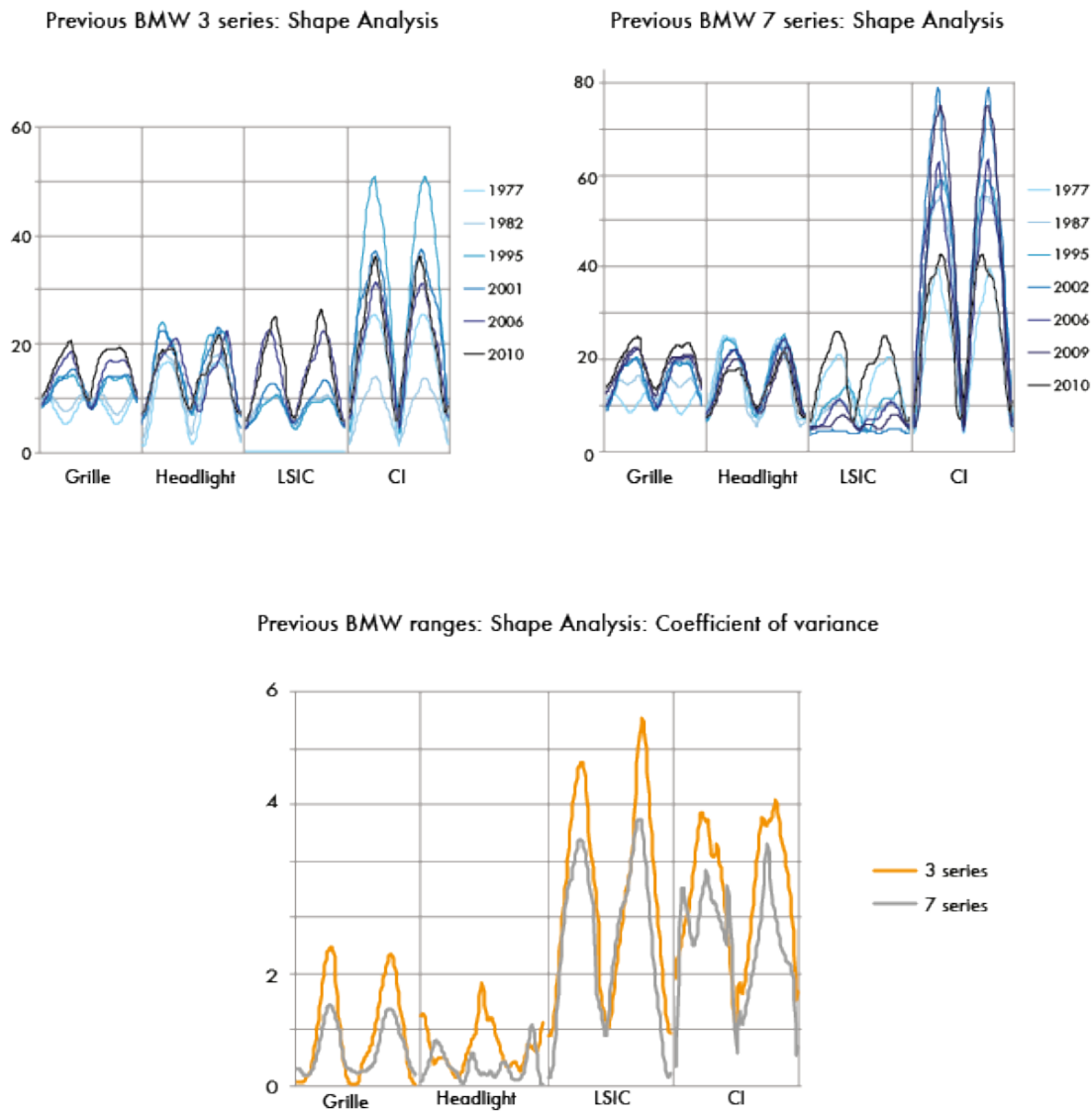


Figure 118 Charts showing the resulting shape plots from shape analysis and plotting the coefficient of variance in shape of features across previous models of BMW 3 series and 7 series

Model competition analysis

This section presents results and observations from the application of analyses to two groups of vehicles consisting of vehicles considered to be in direct competition with BMW 3 series and BMW 7 series respectively. For this analysis the main emphasis in observation is distinctiveness of the BMW vehicles within their respective competing groups.

Proportion analysis

To observe distinctiveness, the BMW difference from the mean (d) is compared with the value for standard deviation (SD) of the group of competing models of different brand. This comparison is shown in Figure 119.

From Figure 119 It can be seen that distinctive proportions are largely associated with the grille feature. This finding is unsurprising and perhaps trivial as major difference in grille shape is obvious from simple inspection. While the finding itself may not be of use, the level/degree to which the split grille is different may be of use.

Excluding relationships with the grille, proportions among direct competitors are largely indistinct. This is reflected in Figure 119 showing that the difference from the mean of BMWs is of similar magnitude to the standard deviation of competing groups. In other words the difference of BMWs from the mean is no greater than the typical variation from the mean seen in all models of competition.

Orientation analysis

Figure 120 shows the deviation of BMWs feature positions from the mean of their competition group alongside the standard deviation of said group. These plots are used to summarise the features/coordinates where the BMWs are distinctive within their respective competing groups.

From results for X and Y coordinates two broad observations can be made. The first, seen in both 3 and 7 series plots, is that the Grille feature repeatedly deviates from the mean more than the standard deviation. In other words, $d > SD$. In the X coordinate the grille is the only feature to demonstrate such a level of distinctiveness. This reflects the use of the split grille where the competition uses a more traditional style of grille (also observed and discussed in proportion analysis). In terms of consistencies it is observed that the X coordinates of the headlight are relatively consistent. This is shown in the low measure of distinctiveness and standard deviation.

The second broad trend seen in plots for the Y coordinate is that the BMW features are consistently distinct from the competing group ($d > SD$). It is contended that this is largely due to the method for calculation/definition of positions. In this analysis orientation is measured as a relative value from the badge feature (discussed in **Error! Reference source not found.**). Thus the distinctiveness highlighted in this observation is largely a symptom of the BMW badge being located higher than its competitors. It is however noted that the deviation in the Y coordinate of the LSIC is substantially greater than the difference in badge height. In other words, if the badge position is normalised, the position of the LSIC is still distinctive from the competition.

In summary it is observed that the majority of distinctiveness in BMW are as a result of the interrelationship between grille and badge features with rest of the features. The greatest deviation observed is in the relative heights of features (Y coordinate).

Shape analysis

Results from shape analysis are shown in Figure 121 and observations made. Figure 121 shows shape plots for features of BMW 3 series and 7 series along with shape plots from their respective competing groups. Figure 121 also summarises distinctiveness by comparing the difference of BMWs from the mean with the standard deviation of their respective competing groups.

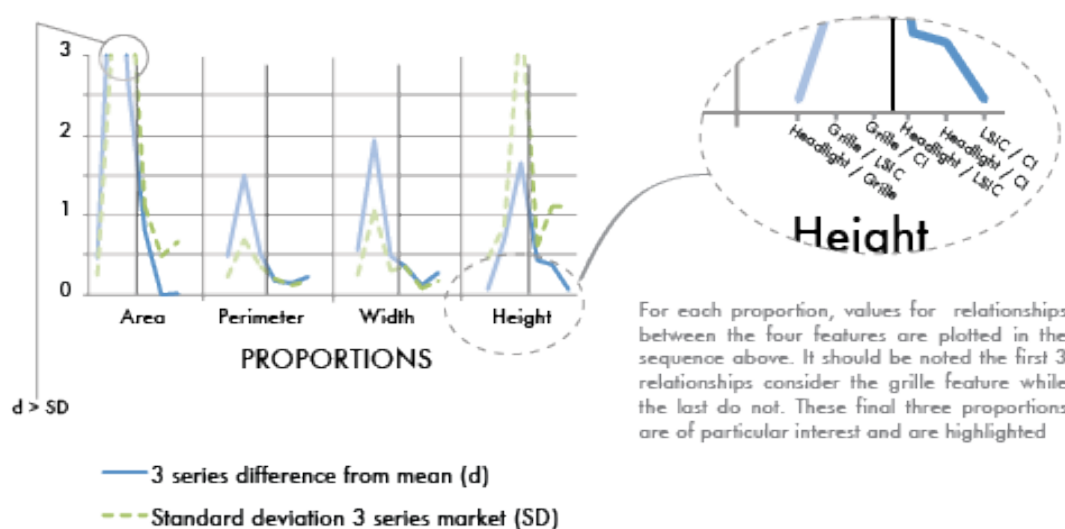
From these charts it can be observed (as with other analyses) that the grille feature is most distinctive. This is manifested in shape plots through lower amplitude, asymmetry and lower rate of change in gradient at peaks all which result in $d > SD$.

Other features are shown to be relatively indistinct in terms of shape with d smaller or of similar magnitude to SD .

The headlight feature can be seen to be the most consistent in shape across both competing groups. The CI in the 7 series competing group exhibits the least consistency of the features analysed.

The final observation made is in the similarity in the feature shape plots for the BMW grille, headlight and LSIC. This would suggest similar forms are perpetuated through the design of these features. Perpetuation/consistency to this degree is not observed in any of the other competing vehicles, mostly due to the grille feature being significantly larger in scale.

3 series competition: Difference from mean in proportions



7 Series competition: Difference from mean in proportions

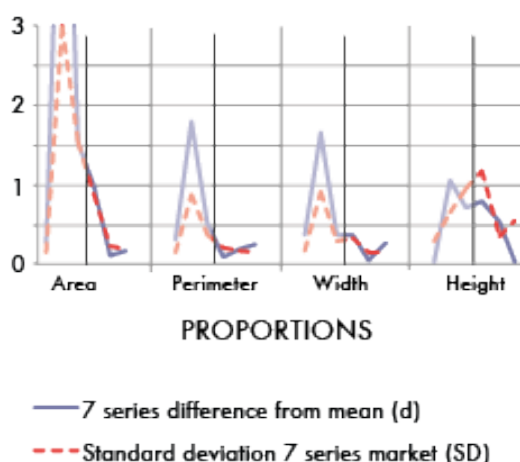
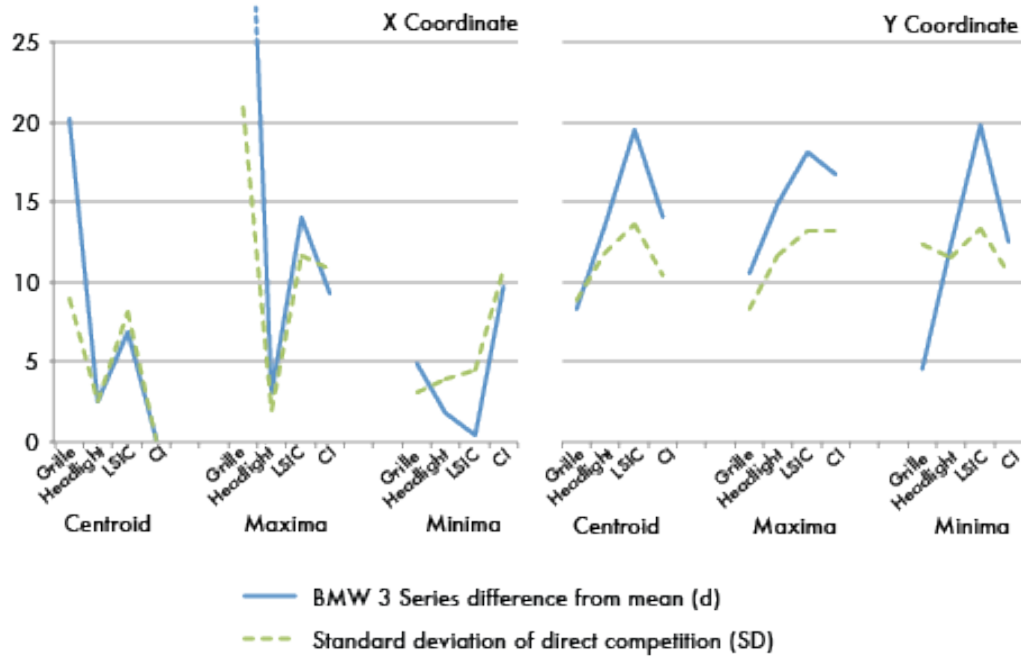


Figure 119 Plots summarizing the distinctive proportions of BMW 3 series and 7 series features relative to their direct competitors of different brands.

3 Series competition: Difference from mean in orientation



7 Series competition: Difference from mean in orientation

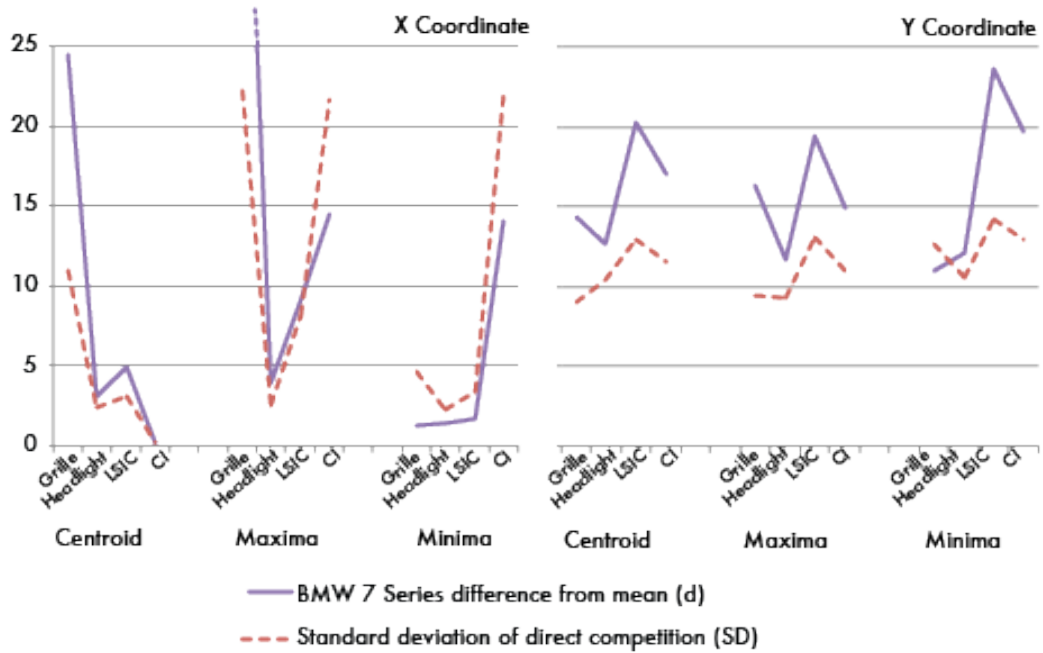


Figure 120 Distinctiveness of BMW 3 series and 7 series from competition in feature orientation

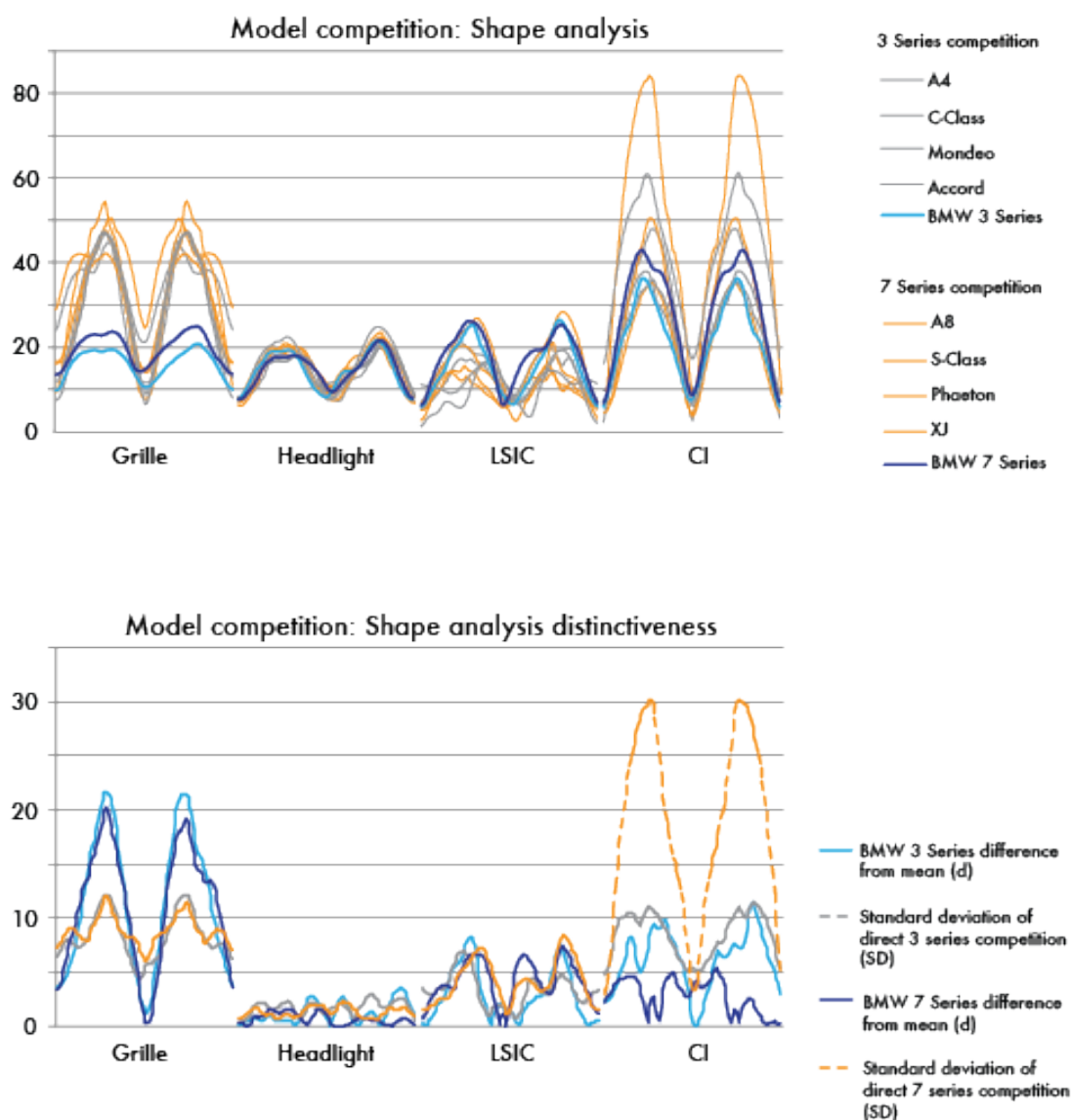


Figure 121 Charts showing the resulting shape plots from shape analysis and plotting the difference of BMW 3 series and 7 series from the mean alongside standard deviation of their respective competing groups to show distinctiveness

Range competition analysis

This sections reports observations relating to the investigation of appearance bewteen three groups of products from three competing manufacturers. In these results particular emphasis is placed on consistency across brands with respect to their distinctiveness from competitors.

Proportion analysis

From proportion analysis there is no relationship that is significantly distinct from the both Mercedes and Audi with the exception of the grille width. As with previous investigations this is due to the use of the split grille in BMWs. In terms of consistency it can be seen that all of the three ranges exhibit similar degrees of consistency in

proportions, illustrated in Figure 122. This indicates that none of the brands use high or low level of consistency to make their range distinct from competition.

Orienataion analysis

Similar to results from the proportion analysis, it is observed that the BMW range does not indicate any major distinctiveness in terms of the orientation of features with the exception of the maxima of the grille. This is demonstrated in Figure 123 in plots for the mean X and Y coordinates. It is observed that none of the three ranges investigated is significantly 'distinct' or different in magnitude of variance.

Notably from plotting consistency of feature orientation it is observed that the BMW range is the least consistent of the three ranges investigated. The orientation of the LSIC is noted as being particularly variable across the BMW range.

Shape analysis

Again, as with previous analyses, the BMW grille shape is observed as being distinct due to its split kidney form. Aside from this obvious distinction there can be seen some more subtle distinctions in shape between competing brands. Despite the headlight shapes being predominantly similar/indistinct, it can be seen from the mean shape plot that the Audi headlight has a sharper and more pronounced (first peak). Similarly the Mercedes deviates in a simalar way in its second peak. It can also be observed that the Mercedes LSIC shows a more distinct shape plot from its competitors.

In terms of consistency, it is observed that the three brands demonstrate similar levels of consistency in shape. This is reflected in the similar magnitudes of coefficient of variance of feature shape plots in Figure 124. The one exception to this is in the Mercedes CI which is shown to be significantly more inconsistent than other brands/features.

It is noted however that some features exhibit a maximum point in variance on their contour. This suggests that there are specific points on the contour of features of a certain brand at which shape deviates within said brands' group. Examples of this can be seen in the BMW and Audi headlight, and BMW and Mercedes LSIC (variance plots).

Competing ranges: Coefficient of variance in proportions



Figure 122 Plotting the coefficient of variation of proportion between features in area, perimeter height and width for BMW, Audi and Mercedes ranges.

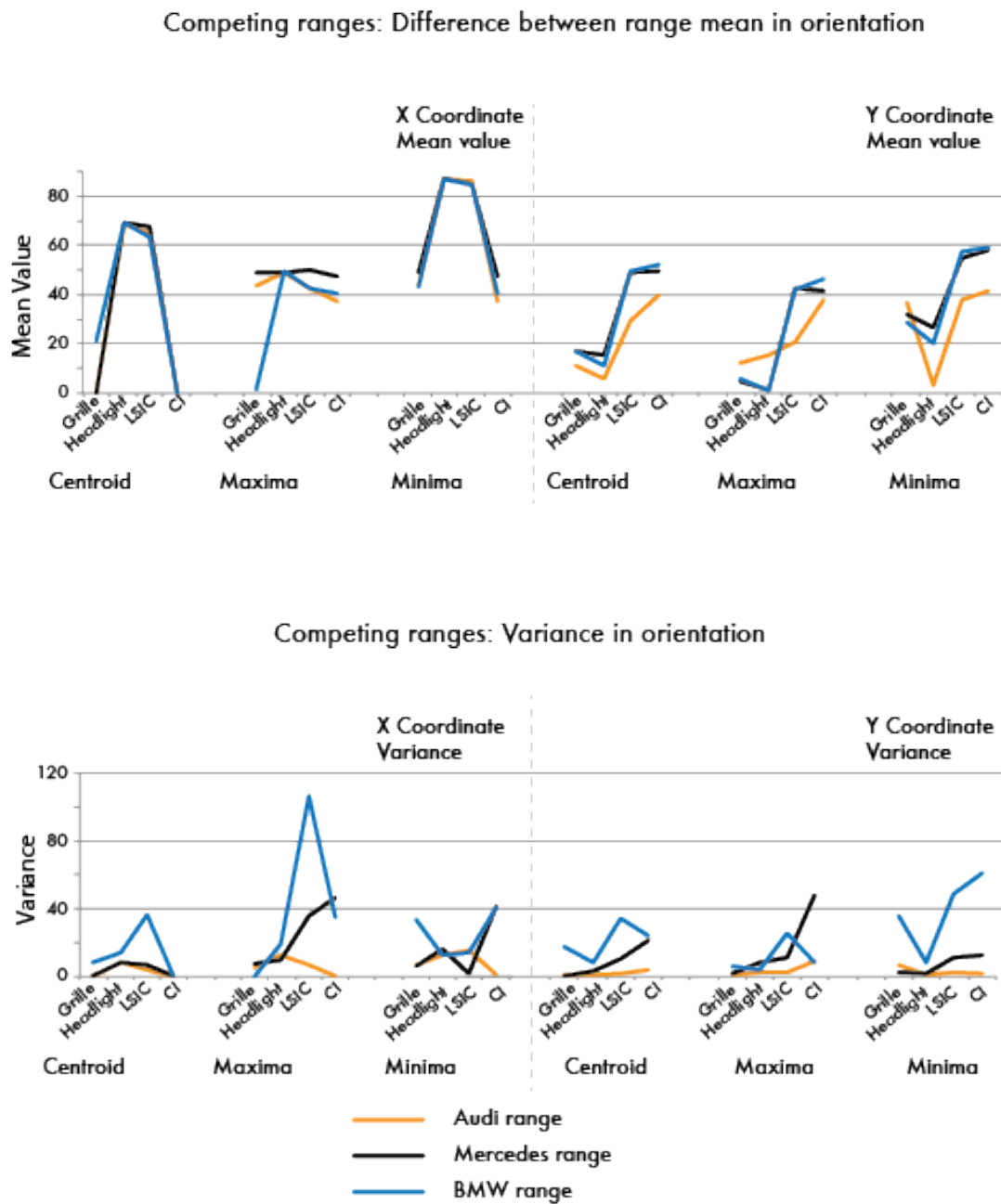


Figure 123 Plots to illustrate the distinctiveness of BMW range from competing brands, and consistency in the orientation of features

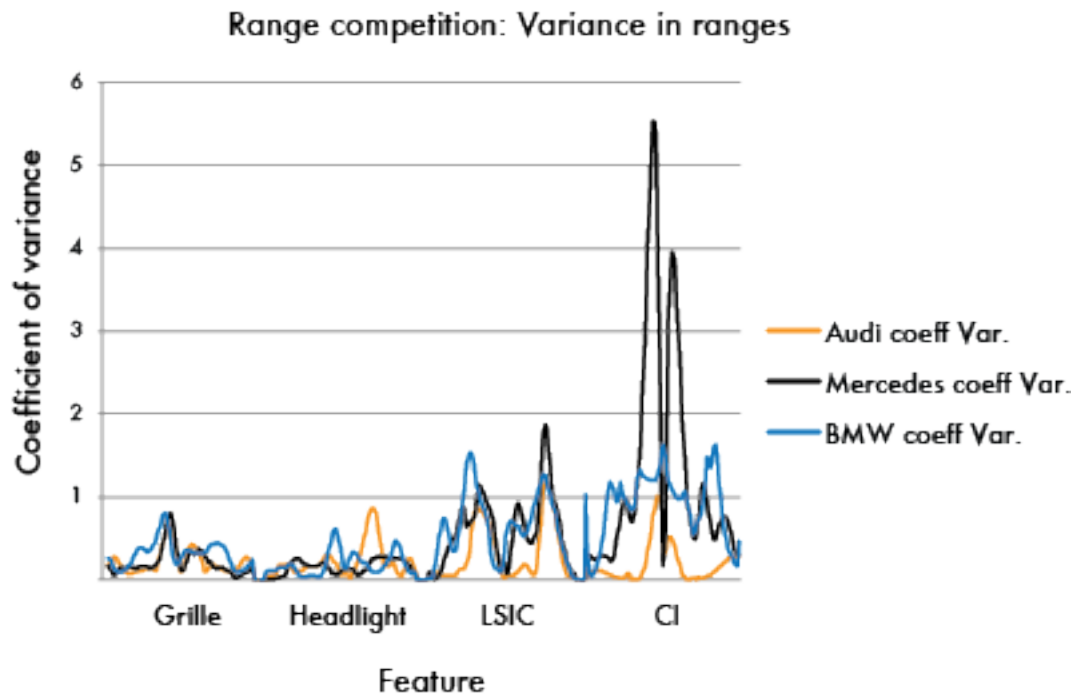
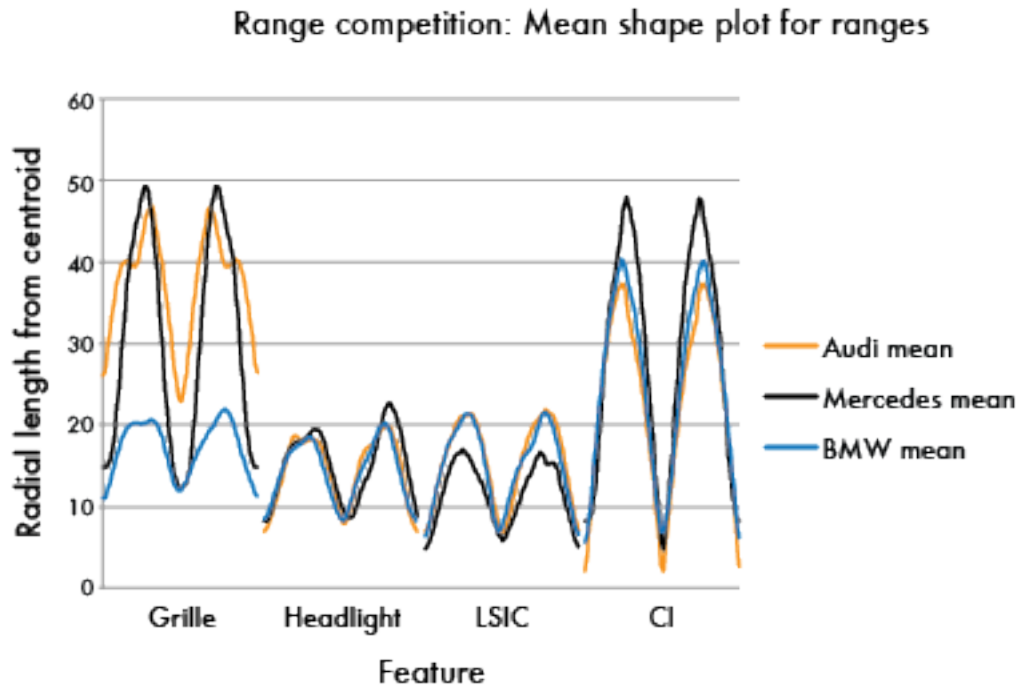


Figure 124 Charts showing the mean shape plots and coefficient of variance in shape plots for the three competing groups of products.

To summarise range competition it is seen that the BMW range is relatively indistinct from the other brands assessed. Similarity is particularly noticeable in orientation and proportion where the only distinctiveness is in the split grille and to some extent from badge position. The most distinctiveness is seen in shape, although still relatively low and inconsistency in the visible aspect of a thing; now usually in narrower sense, shape, configuration, as distinguished from colour orientation of the LSIC.

This is illustrated in Figure 125 in which the bounding box of features are shown overlayed. It can be seen there is a clear trend in the proportion and position of features.

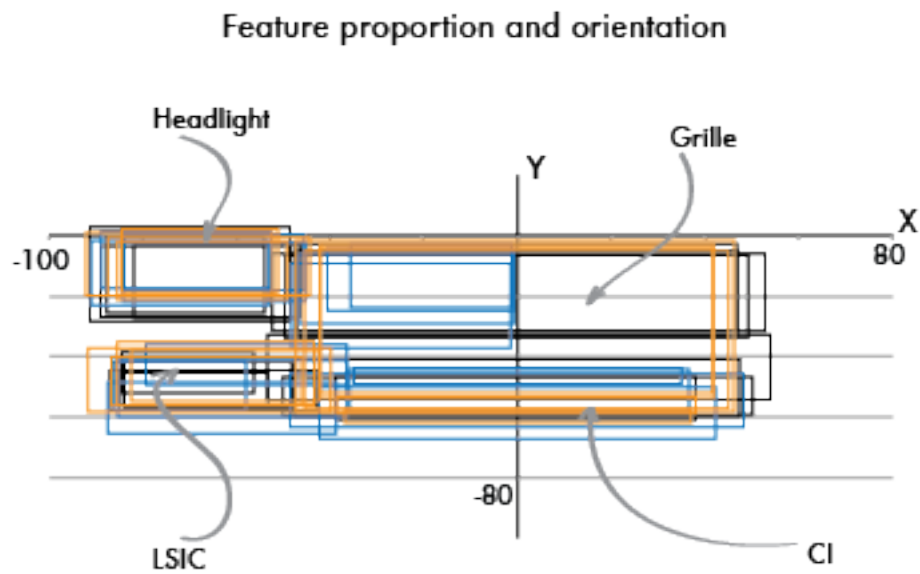


Figure 125 Normalised plot for feature proportion and orientation of all vehicles reviewed in the range competition